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DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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THE ROAD MOVEMENT.

BY LEWIS M. HAUPT, Consulting Engineer.

[*A lecture delivered before the Franklin Institute, November 11, 1892.*]

Professor Haupt was introduced by the Secretary of the Institute and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Undoubtedly this is an age of improvement, and great strides have been made in adapting the resources of nature to the wants of man, yet if we scan the horizon of progress we will discern certain streams of development extending far beyond the general contour which marks the advance of the arts and sciences, while others may be discovered lagging far within the perimeter of progress, oppressive by their very proximity.

The symmetrical development of our transportation lines, as a system, demands that public interest and attention be

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ROAD VI

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VIEWS

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concentrated upon those which have not kept pace with the march of improvement, and that they be advanced to a much higher stage of efficiency.

In a previous lecture* on ship canals, attention was directed to the mutual dependence of the ships and the car on the one hand, and the car and the cart on the other, but little was said about the relative cost of movement by this latter mode of conveyance. It was shown that the waterway was by far the most economical for manifest reasons, being as low in some cases as one-twenty-sixth the cost by rail. In attempting to make a comparison between rail and road the question is more complicated because of the greater range of resistance to be overcome in the latter, depending upon grades, character and condition of surface, friction and many other factors, but as it is the earth road which forms the connecting link between the farm and the station it will be taken as a basis of comparison. On an ordinary road, dry and in good condition, the cost of hauling a ton one mile is variously estimated at from fifteen to twenty-five cents on a level. Taking the least cost, fifteen cents, and comparing it with the least cost by rail, say four mills, we see that the cost of movement by road is at least thirty-seven and one-half times greater than by rail. But at certain seasons of the year the limit of this ratio runs up to infinity, as it is impossible to move a load at any cost; and the railways

* *Vide Franklin Institute Journal*, November, 1892.

that are dependent upon local delivery must side-track a large portion of their rolling stock until Dame Nature comes to the rescue and hardens the road, either by a drying or freezing process. Taking the extremes, therefore, we find the cost of the ton-mile on land may be 900 times that on water, and the importance of improving the roads become impressive as an economic problem. It is not surprising that the farmers complain. Various estimates have been made of the saving due to even a slight improvement of the

From "Good Roads."

surface, so as to enable three horses to do the work of four. In Great Britain this economy has been placed at $100,000,000 per annum.

The cost of keeping a horse is stated to be about $125 a year; this would, therefore, represent the tax which is imposed upon the owners of teams by the failure to improve the road surface to such an extent as to dispense with one horse.

On the portion of the farm products of Pennsylvania which is sent to market, the difference between the cost of

hauling on a clay or on a macadam road is over $200,000 per annum. Were this amount expended by the State in permanently improving the roads, it would not be long before the people of the State would be that much better off and the price to the consumer would be reduced, while the producer would have as large or even a larger margin on his products. To move the hay crop alone caused a loss of $1,560,000, while the total loss due to bad roads aggregates not less than $6,000,000, or the interest on $100,000,000.

At a recent agricultural convention it was stated that, "In the last fifty years $200,000,000 had been spent on roads in Pennsylvania and that $7,000,000 are now spent annually with nothing to show for it." "At the high rate of $10,000 per mile this would macadamize about 700 miles or ten miles in each county. This large sum is lost each year in throwing clay into the road, which works back to clog up the ditches."

Roads should be built continuously and not in patches. Work should be conducted at all seasons and not be made subservient to other interests, when it may suit the convenience of the taxpayer to work out his dues. Their locations and grades should be revised to meet the requirements of the amount and kind of traffic passing on them. They should have continuous and systematic supervision. These and many other conditions should be fulfilled that we may remove the wasteful and disgraceful condition of our highways and greatly increase their utility and the economy of transporting the almost unlimited resources of this great Commonwealth over them.

In looking for the cause of the neglected condition of our highway system, we find it to result largely from the ignorance prevailing amongst agriculturalists as to the economy of good roads, and the mistrust lest a money tax may be appropriated to some other purpose or disappear in the pocket of dishonest officials. As the rural districts have a large representation who desire to conform to the wishes of their constituents, it becomes difficult to secure the passage of any law which would radically change for the better our methods of building and repairing roads without their

sanction. On this point, our esteemed ex-Governor, Hon. James A. Beaver,* in his paper, entitled "Why we have so Few Good Roads," recently said: "The main difficulty in the case is perhaps to be found * * * in the indifference of the general public upon the subject."

Yet, "most people are interested in securing a better condition of the common roads of the country for their own convenience and pleasure. But the disposition to antagonize a forward movement in this respect, or to retard an intelligent and comprehensive administration of present laws, is based perhaps upon the fear of the amount of money necessary to be expended in securing, in the first instance, a thoroughly good road. In all discussions of the subject, this seems to be the final resort of those who oppose improvements upon the present system."

This objection is not limited to roads, but is the battle cry of obstructionists generally. The "great cost" of a project is the *bête noir* of many an urgent and important public work, and the fear of increased taxes has sounded the death-knell of many an improvement which would have lightened the burdens of the community and added greatly to the pleasures and comforts of life.

The cost of even the grandest of public works, however great, if honestly administered, will be returned to the taxpayer many-fold. In our own city we have excessive wear and tear from ruinous pavement which under a wise and systematic administration are being gradually removed, but still there are other works quite as necessary restrained on the same plea of too great cost; *e. g.*, the boulevard, the harbor front and the water supply, for each and all of which there is an urgent demand that Philadelphia may maintain her honored position as one of the foremost cities of civilization. But the conservatism which forces us into the old footpathway of our forefathers retards our rapid movements and condemns us to the wear and tear of the tread-mill.

Continuing, Governor Beaver adds: "We are satisfied, or

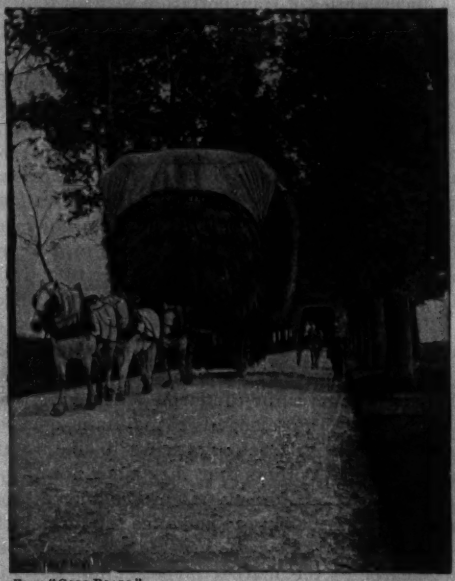
* *The Forum*, August, 1892. "Why we have so Few Good Roads."

if not satisfied with, we endure the system, or lack of system, under which our forefathers blazed their roads through the primitive forests and made their contributions to their maintenance by a few days' work in each year, which caused them to be more impassable than they were the year before." * * * "A good road is cheaper than a poor one, but prejudice, opposition to change and indifference control the masses of our people and dictate the course of legislation. If we are to secure the best results, it is undoubtedly true that we must change the laws enacted fifty or 100 years ago so as to meet present needs and conditions. One of the difficulties in securing a change in our present laws is found in the importance of the subject, which has attracted so much attention, that many of our law-makers have plans and codes of their own which they are unwilling to exchange for those of another."

"Any simple plan which will secure the location of a road (or its revision) by a competent civil engineer, and its construction by a man who is familiar with the principles of road making and is able to give to the community 100 cents for every dollar expended, will reach the results at present desirable and attainable. With us in Pennsylvania the fundamental defect in our law is the right which is given to the taxpayer to 'work out his road tax.' The result of this system is that repairs are made when they are least needed and the smallest amount of work for the largest amount of pay possible is secured." * * "In general our roads are located by those who have no enlarged experience in engineering and who prefer to accommodate their neighbors by following the property lines between them, or making the road near or distant as may suit their convenience rather than to consult the general good of the public."

Governor Beaver then goes on to say that the essentials of a good road are, first, a good location; second, a good foundation; and third, a firm and durable superstructure; and that these may only be obtained at some cost, such as any prudent business man would make to secure permanency and economy in his business affairs. That

no radical reform can be expected to be carried out in a day, but that progress may be made by taking one step forward each time. Quoting again, he says: "If in Pennsylvania and elsewhere, where the system of working out the road tax prevails, we could secure a simple amendment which would compel all taxes for road purposes to be paid in money, as other taxes are paid, and if that money tax were



From "Good Roads."

expended in each municipality by one man of good common sense, we could in a very few years prepare our people for another step forward." Yet a bill embodying these and other features failed to become a law at the last session of the Legislature.

Further, as to the assertion that the railroads have supplanted common roads and rendered them unnecessary, it is quite the reverse since the farmer, who was formerly

so remote that he could not market his excess of products without converting it into live stock which could transport itself, can now in most cases reach a station and there ship by rail at greater profit to himself and benefit to the railroad; but to avoid a glut in the market the road should be made passable at all seasons of the year. This would steady prices and cheapen supplies by saving the wear and tear as well as uncertainties of transportation without reducing the price at the farm.

Several agricultural societies in this State have passed resolutions denouncing turnpikes and instructing their representatives to vote against them on general principles. This action is easily understood when the reasons are stated. The experience of the counties referred to is unfortunate, in the fact that many years ago some stock companies were authorized to build pikes and levy tolls without sufficient restrictions as to their maintenance. In consequence pikes were built in the old-fashioned way which in a short time became almost impassable from the neglect to maintain the metalling in good condition while the tolls were collected as usual. The consequence is that the stockholders do not want the State to step in and break up their monopolies by making free turnpikes, which would be kept in order and take their patronage, while the farmers believing that they would be taxed still more heavily to maintain some political sinecures, conclude it is better rather "to endure the ills they have than fly to others that they know not of." Such, then, are the practical difficulties in the way of securing legislation. It is necessary to convince the farmer that he will be benefited, his taxes be lowered and his property be brought nearer to the market in both time and distance before much progress can be made. This is being done in the best possible manner by the various townships near our larger cities in constructing macadamized roads in these sections. Gradually the work goes on and the contagion is spreading to the more remote and sparsely settled districts, but here the cost per capita is too great and the State should be allowed to assist. In fact, there are some roads in the State which, from the peculiar physical conditions surround-

ing them, are of no use to and cannot be used by the people living in the townships which they traverse. I refer to those highways skirting the base of a mountain on the one hand and a river on the other. This grand old Keystone State, so rich in resources, so progressive in manufactures, agriculture and commerce, so well provided with railroads, and so free from debt, is unfortunately hampered with a broken topography, intersected by as miserable a system of roads as can well be found in any State of the Union. It was my misfortune, a few years since, to have to travel on the "turnpike" from Lancaster to New Holland, about ten miles, in the regular stage. It should have been traversed in 100 minutes but it took 300, and the pike was said to be in "good condition." Ten miles in five hours was the rate. A good walker could cover twice the distance in the same time. I found it much pleasanter to walk than to ride. The irregularities of the road between Harrisburg, the capital, and Gettysburg, the college, which I traversed in a stage some forty-odd years ago, are still indented upon my cerebral chronograph so deeply that I have ever since been "stage-struck."

Yet when it is seriously proposed to soften the asperities of life and mend our ways by the application of science and common sense, we are repulsed with the invincible argument that our grandfathers endured these hardships and it made them tough and manly, why should not we and our children follow in the same rut?

Against such an opinion arguments are unavailing, for

> "The man convinced against his will,
> Retains the same conviction still."

But the road movement is growing and gaining in favor and popularity, and there is no organization that has done so much as a body to promote it as the "*wheelmen*." A hard and smooth road surface is to them what air is to a bird or water to a ship, and yet it is no more essential to the cyclist than to the agriculturalist, the only difference being that the former supplies his own power and hence knows its value, while the latter simply holds the reins and whip which propel and control his animal motor.

If the teamster attempted to pull his own truck he would be convinced of the difference in resistance between a mud road and a macadamized pike in ten minutes, and you could not drive him off the pike if the tolls were made a dollar where they are now a cent.

In reviewing and summing up the opinions advanced by the competitors for road prizes, recently offered by a committee of our public-spirited citizens, and published under the title of *A Move for Better Roads*,* I concluded "there are serious objections to the stock company proposition, as it prevents uniformity of action and equitable taxation. Some roads will cost less and be taxed more than others, and it is always difficult to enforce a standard as to the condition of the highways or to compel companies to maintain it.

"The plan which commends itself to the writer as being the simplest, the most direct and least objectionable, is that of State aid under proper restrictions. For example, let the amount desired be voted for the construction (not maintenance) of permanent roads, to be divided pro rata amongst the counties making appropriations from their own funds for a similar purpose. * * * No public work of this kind should be undertaken until a competent civil engineer is appointed to represent the interests of the State, who should carefully revise the character and location of every road before the work of metalling the surface is authorized. The economy effected by this plan will soon save far more than the expenses of the office in cost of maintaining the roads, and the indirect benefits by reduction of tractive force would be incalculable. The best is the cheapest in this case, and it is well said that "the man who works for nothing is not worth his board." While other States find it to their interest to maintain an engineer, Pennsylvania has been and is content to entrust the supervision of her public works to the rotation of a political office, and suffer accordingly from indifference and neglect. Upon this point a well-known authority, in commenting upon the changes so frequently

*Wm. H. Rhawn, Chairman, Philadelphia. H. C. Baird & Co., 810 Walnut Street, Philadelphia, publishers.

made in our public service, said, "Men dealing with interests so vast should not be subject to constant changes. Change of Commissioners means change of methods, and change of methods during the prosecution of engineering works is very likely to mean disaster."

I am well aware that there is serious objection to State aid, but it arises from the lack of patriotism, so prevalent in times of peace, and the fear lest some one section may be unduly favored at the expense of another. There is the

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further plea that it is unconstitutional, the last resort of a man or a party without an argument when he is opposing an appropriation of public works. But this is answered by quoting the words of the revered Thomas Jefferson, whose house stood but a stone's throw from this Institute, and who aided in framing the Constitution. He said that the *imposts should be maintained, and that the surplus created should be appropriated to the improvement of roads, canals, rivers and education.* He placed roads first and education last, perhaps having in mind the maxim that there is no royal road to

learning, and thinking it necessary to provide the way first, knowing that the education would follow.

In these days the order seems to be reversed, as education must now precede road construction and legislation.

Again it is decreed in Article 1, Section VIII of the Constitution, "Congress shall have power to establish post offices and post roads," whereby jurisdiction is clearly vested in the Federal Government to undertake the construction of roads and the regulation of interstate commerce, even more explicitly than for the improvements of rivers and harbors.

Under and by virtue of this authority the Government has already vested large sums of money in the construction of military and post roads, and in subsidies and bounties to railroads and transportation companies to encourage and stimulate intercommunication.

At the recent meeting of the League of American Wheelmen in Washington, prior to the close of the first session of this Fifty-second Congress, resolutions were adopted calling upon that body to create a highway commission to consider the question of the extension of national highways, and the granting of Government aid in their construction. This movement seems to be the centralization of the efforts which are making in almost every State and Territory of the Union for the improvement of our roads. And it has been focused in the passage of a bill through the Senate providing for a commission consisting of two Senators, five members of the House of Representatives, and five citizens to be appointed by the President of the United States, making twelve in all, whose duty it shall be to frame a measure looking to the best method of securing and encouraging some systematic plan for the general improvement of our highways.

The bill creating this commission is expected to pass the House early in the coming session, and become a law without a dissenting vote. The promoters of this movement called a meeting at the opening of the Columbian Exhibition, October 21st, at which the representatives of the various States and local societies, Boards of Trade, Chambers

of Commerce, Farmers Association, Leagues of American Wheelmen and all other public or private bodies interested in road improvements were invited to be present to effect a preliminary organization for a National League.*

At this meeting, with over 1,000 persons present, a temporary organization was effected, consisting of Hon. Chas. F. Manderson, U. S. Senator from Nebraska, President; Gen. Roy Stone, Vice-President and Secretary; and our esteemed fellow-citizen, Mr. Wm. H. Rhawn, President of the National Bank of the Republic, Treasurer.

Ten directors were also selected from amongst our distinguished and patriotic citizens. They are men of so great weight and influence that the mere recital of their names is an earnest endorsement of the movement with which they are thus identified. The directors are:

Hon. E. H. Thayer, of Iowa; Philip D. Armour, of Illinois; Leland Stanford, of California; Clem. Studebaker, of Indiana; Samuel W. Allerton, of Illinois; Chauncey B.

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* The signers to the call were:

E. H. Thayer, President Iowa State Road Improvement Association.
Fredk. Fraley, President National Board of Trade, Philadelphia.
P. S. Townsend, Chairman Committee on Roads, National Board of Trade.
Lewis M. Haupt, C. E., Secretary Committee on Better Roads, Editor of *A Move for Better Roads*.
Hon. S. M. Cullom, U. S. Senate (Illinois), Chairman Committee on Interstate Commerce.
Hon. Chauncy B. Ripley, Vice-President New Jersey State Road Board.
Hon. P. S. Post, M. C., Illinois.
Hon. Chas. F. Manderson, U. S. Senate (Nebraska).
Isaac B. Potter, Chairman Committee on Improvements of Highways, Law Secretary New York State Roads Improvement Association.
Chas. Q. Eldridge, Secretary Board of Trade, Hoosick Falls, N. Y.
Albert G. Porter, Indiana.
Clem. Studebaker, Indiana.
Hon. Dan. Waugh, M. C., Indiana.
Wm. P. Dillingham, Vermont.
Leavitt Hunt, Vermont.
Hiram A. Huse, Vermont.
Edward Browning, Pennsylvania.
Wm. A. Stone, M. C., Pennsylvania.
Roy Stone, New York.
J. H. Fisher, Secretary Committee on Roads National Board of Trade.

Ripley, of New Jersey; Alexander J. Cassatt, of Pennsylvania; W. Seward Webb, of New York; Col. Albert A. Pope, of Massachusetts; Chas. L. Burdett, of Connecticut.

The name of this organization is the National League for Good Roads, a name sufficiently suggestive of its purposes and the composition of its board is a guarantee that good results will follow.

The permanent chairman is now Hon. E. H. Thayer, President of the Iowa State Roads Improvement Association, and S. K. Thornton Prime, of Dwight, Ill., Secretary.

Time does not permit me to refer specifically to the indefatigable work of Col. A. A. Pope, of Boston, in his efforts to aid this movement in every conceivable way, and his excellent practical suggestions and liberal endowment of a chair for instruction in road construction, nor to the admir-

---

Thos. Sturgis, Secretary Committee on Roads, "New York Farmers," New York City.
Edward Burrough, President State Board of Agriculture, New Jersey.
Franklyn Dye, Secretary Road Improvement Association of New Jersey.
Ambrose Snow, President New York Board of Trade and Transportation, New York City.
Horace Porter, New York.
F. B. Thurber, New York.
Hon. Walter I. Hayes, M. C., Iowa.
Chas. W. Stone, M. C., Pennsylvania.
Hamilton A. Hill, Secretary National Board of Trade, Boston.
Levi Chubbuch, Secretary Missouri State Board of Agriculture.
Lucius Fairchild, Wisconsin.
J. A. Potts, President Missouri State Board of Agriculture.
Edward D. Porter, Dean College of Agriculture.
J. S. Hull, *et. al.*, Commissioner of Erie County, Ohio.
Millard F. Lane, Chairman Committee on Roads National Carriage Builders' Association.
J. L. Erwin, President Missouri Road Improvement Association.
J. K. Gwinn, Ex-Commissioner Missouri World Fair Board.
Norman J. Coleman, St. Louis.
Geo. Longman, St. Louis.
C. D. Coleman, St. Louis.
J. W. Hodgkin, St. Louis.
J. P. Blake, St. Louis.
G. L. Whidby, Secretary Georgia Road Congress.
W. L. Webr, Chairman State Highway Committee of Michigan.

able object lessons which are so largely disseminated through the practical periodical, entitled *Good Roads*, published by Mr. Isaac B. Potter, of New York, nor to the general interest manifested in this subject by numerous engineering, technical and trade journals, which are full of terse and practical articles on the subject. In fact, the awakening is general, and no legislator need feel that the press is lukewarm on this subject, or that it will call him to account for sustaining any revision of the law which will

From "Good Roads."

improve the condition of our common roads. The provisions to this end are briefly these:

(1) Abolish the system of working out the road tax and collect it in cash like any other, paying the laborer in legal tender.

(2) Provide for a revision of the grades and alignment of all roads which are to be made "permanent" by metalling, by placing them under the supervision of a competent engineer.

(3) Regulate the width of tire and length of axles so as to convert the wheels of heavy vehicles into road preservers instead of road destroyers.

(4) Require constant supervision and attention by road-

men regularly employed to maintain the structure in the best possible condition at all seasons of the year.

This does not require that the road should be metalled where stone is scarce, but a man who understands his business will soon learn how to prepare an earth surface so as to obtain from it the best service.

These few requirements embodied in a law would effect a remarkable difference in the efficiency of our road surfaces and great economy in their maintenance. To secure such modification, however, it becomes the duty of everyone interested in the subject of good roads (and who is not?) to impress upon his representative in the State or National Legislature, by letter or by personal solicitation, the importance of taking some action looking to the revision of the road laws and providing for improvements in their condition, otherwise, "what is everybody's business becomes nobody's business," and the roads remain impassable quagmires for a large portion of the year. Concentration of effort is as necessary in this matter as in any other great undertaking, and unless every citizen will bring his influence to bear at the State capital but little can be expected in behalf of these interests.

As words are inadequate to convey correct impressions of actual physical conditions, let us look at some photographs of good and bad roads collected from Norway, Switzerland, Germany and Ireland, and contrast them with some of the mud roads of our own country. They will serve to impress the importance of the theme upon any who may still have doubts as to the utility of good, hard-surfaced roads.

[The lecture closed with an exhibition of some fifty striking photographs. The illustrations printed in the text (except the first) are typical European roads. The frontispiece needs no explanation.]

DEVELOPMENT AND CONDITION OF THE COKE INDUSTRY BY THE UTILIZATION OF BY-PRODUCTS.

By B Leistikow,
General Director of the Wilhelms Factory at Enlau, Wilhelmshuette.

Translated by Henry A. Wasmuth, M. E.

[*Address at the fifth meeting of the German Mining Engineers, held at Breslau, September 5, 1892.*]

Industrial innovations, promising considerable profits, as a rule are introduced eagerly and soon become common property. This cannot be claimed of a branch industry, the distillation of coal with saving of by-products, of which I will treat especially to-day.

The distillation of coal consists in the carbonization of coal in closed chambers, *i. e.*, the expulsion of volatile matter by heat externally applied. The remaining solid residue, carbon, is termed coke.

The object of the dry distillation of coal is twofold, according as the volatile matter or the solid constituents are considered as principal products. The yield of volatile matter as principal product is the object of the manufacture of illuminating gas, and the remaining solid constituents are by-products. The gain of the solid constituents by the distillation of coal is the object of the manufacture of coke and the products of volatile matter are saved as by-products.

I will treat the saving of these by-products of the coke industry and its development, illustrating the subject by means of drawings furnished by Dr. C. Otto & Co., of Dahlhausen, Germany.

With the introduction of the manufacture of illuminating gas about 1820, was connected also from the beginning the gain of tar and ammonia, but the rational saving of these by-products of the coke industry is of a later date, for no material results had been attained ten years ago. Per

haps, the reason has been that, on account of moderate competition, the value of coal and coke was greater and there was little inducement to seek for higher profits, to be realized by costly experiments, and this indifference was strengthened by the erroneous opinion that obtained, that the quality of coke was impaired in the process of saving by-products.

The oldest reports of saving tar from coke ovens date from 1768, and according to those reports so called muffle ovens and also coke ovens were in operation, by which tar was saved, at Sulzbach near Saarbruecken. But it seems that those first trials were not successful.

Archibald Cochrane, Earl of Dundonald, obtained a patent in 1781 to gain tar, volatile oils, alkali, acids, pitch and coke from coal by the combustion of the coal itself, without external heating. This first trial in England also was without success.

Knab in Commentry, Department Allier, France, erected a group of coke ovens with saving of by-products in 1856 and adopted for them the apparatus similar to that used in the manufacture of illuminating gas. The ovens were 2 metres wide, 1 metre high, 7 metres long, and with bottom heating. The gases, deprived of tar and ammonia were conducted back to the ovens, still in use to-day, and burned under the bottoms of the ovens. A comparison of the results obtained by Knab with those obtained to-day shows that the former were insufficient, principally on account of the considerable width of the ovens, and partly due to the quality of the coal. Such ovens, it is said, are still in operation at Flênn near Mons. The priority of Knab is contested, for it is reported that fifty ovens of the Powels-Dubochet system were in operation near Saarbruecken in 1854; the by-products were not saved, for the products of distillation were burned under the ovens. The ovens were only designed to gain a higher percentage of coke, for the carbonization took place in air-tight closed chambers. Such ovens were also in operation at La Villette, Department Seine, in 1860, producing an excellent furnace coke, besides a poor gas, which was mixed with rich gas from the usual gas retorts. As the gas was used for illumination it

is obvious that tar and ammonia must have been condensed.

Patents were obtained by Jones and Blackwell in 1861 to save tar and ammonia water by coking coal in piles, but without success. The Knab ovens were improved substantially by Carves in 1862, by heating besides the bottoms, also the side walls by flues. The gases from the air-tight closed ovens were exhausted, and cooled, and conducted to coke scrubbers to be deprived of tar and ammonia, and then to be used for heating the ovens.

Fifty-three Knab-Carves ovens were erected at Bessêge, Department Gard in 1873, and 100 ovens at Terrenoire near St. Etienne, Department Loire, in 1879. After many experiments the ovens were given a width of only 0·6 metre, in order to cause a better penetration of the heat. The gases from the coking process, deprived of tar and ammonia, were conducted to a small grate by a tube and here consumed. The combustion products pass under the bottoms of the coke ovens, ascend to the upper of the three side flues, and finally descend through the side flues into the main canal and to the chimney.

The construction of the Knab-Carves ovens was adopted by Albert Huessener for the construction of a coal distillation plant at Bulmke, near Gelsenkirchen, and to this gentleman is due the credit of being the pioneer for saving by-products of the coke industry in Germany. Huessener first erected 100 ovens with coal distillation in Germany in 1881, and demonstrated that this industry could be made successful.

Numerous new constructions succeeded each other, but not all of them were well received, especially because the prejudice, already mentioned, that the quality of coke was impaired by the exhaustion of gas, was hard to overcome. There was also a general apprehension that German coal in comparatively cold running ovens would furnish a bad coke.

The credit of overcoming these prejudices and of constructing and introducing an oven which meets the highest requirements, is due to Dr. C. Otto & Co., of Dahlhausen on

the Ruhr, and especially to Dr. Otto of the firm, who fortunately is enabled to speak here instead of myself, as the foremost representative of this industry; and who, by the erection of ten trial ovens at Holland Mine, November, 1881, laid the foundation of a common system very widely introduced to-day. The oven was perfected by the combination of of Siemens regenerators, patented by Gustav Hoffmann, Superintendent of the Silesian Coal and Coke Works, at Gottesberg, with the Dr. Otto system, and the first ten trial ovens were put in operation at the Carl-Georg-Victor Mine

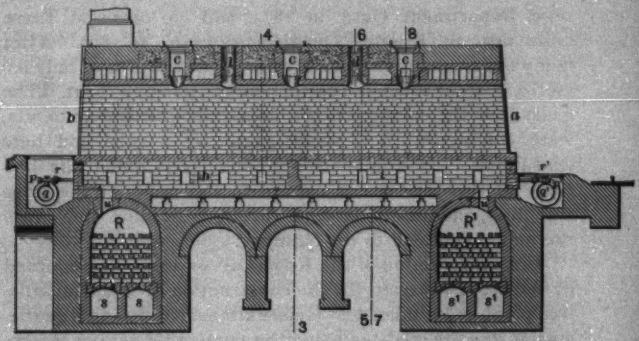

FIG. 1.

near Gottesberg, in 1883, by Director Berndt, who has been prominent in the introduction of coal distillation.

This combination, which I will term Otto-Hoffmann oven hereafter, embraces small chambers of 0·4 to 0·6 metre wide, about 10 metres long and 1·6 to 1·7 metres high to the counter-pillar, closed air-tight by doors on both ends. The construction of these ovens is based on the combination of Siemens regenerators by Hoffmann with the common Otto oven, perfected by numerous improvements from time to time. In May, 1886, there were in operation 500 such ovens, of which 330 were in Westphalia, 110 in Silesia, and 60 in Austria, each oven coking about 1,000 tons of coal per annum, yielding, without regard of the varying yield of

some brands of coal, 750 tons of coke, thirty tons of tar and ten tons of ammonia.

Fig. 1 shows a longitudinal section of a Otto-Hoffmann coke oven, the pusher being located at the end *a*, while the coke is delivered at the end *b*, where it is quenched. Instead of the openings of the common Coppée oven, by which the gases of the coking chamber first enter the vertical flues of the side walls and then pass into the bottom canals to be consumed, there is no direct connection between the coking chamber and the interior of the side walls. In the arch of the oven are three openings *c*, to charge

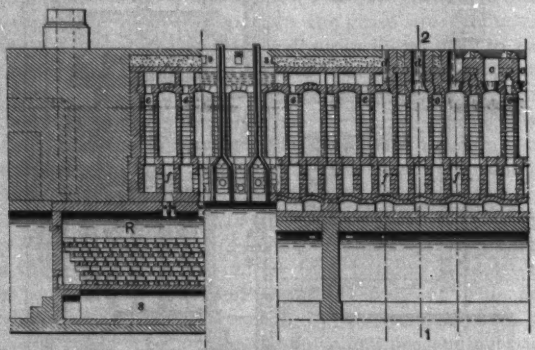

FIG. 2.—Section of oven.

the oven, and two openings *d* by which the gases of the coking process escape. In the side walls below the counterpillar is located a horizontal flue *e*, *Fig. 2*, by which all vertical flues are connected. The length of the bottom canal *f* is partitioned by a wall into two equal parts *h* and *i*. Each of these halves is in connection with a regenerator *R* or *R'*, respectively, in which the air necessary for the combustion of gas is heated. Further, the pipes *p* and *p'*, fed by gas-distributing pipes *q* and *q'*, enter one-half of the bottom canal, respectively.

The regenerators are long canals, latticed by bricks, running transversely beneath all chambers. At one end they

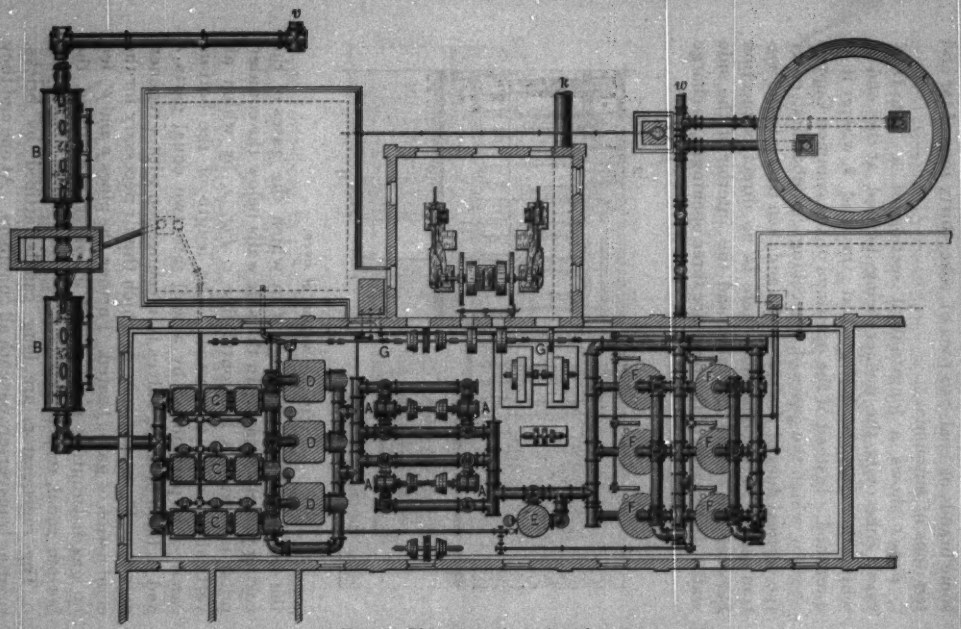

FIG. 3.—Plan of condensation plant.

are in connection by an adjusting trap either with the air-distributing pipe *k*, *Fig. 3*, or backwards with the chimney. As soon as the oven is heated and the coking process is in progress, the gases of the coal escape by the openings *d* into the stand-pipes, similar to those attached to the retorts of gas works, and from there by an open valve into the gas receiver, whence they are conducted by conducting pipe *v*, *Fig. 3*, to the condensation. Here the gas is deprived of the by-products, tar, ammonia and benzole, and then conducted back to the ovens.

Before we describe the condensation we will explain the operation of the ovens by *Figs. 1* and *2*. Assuming that the ovens are in operation, then the gases are conducted to the condensation, as already described, and back to the ovens by pipe line, *Fig. 3*. There is an adjusting trap in the return pipe line by which, according to the position of the trap, the gas enters into gas-distributing pipes *q* or *q'*. If the gas enters into pipe *q* and from here through cock *r* of pipe *p* into the bottom canal *h*, then the trap of the air-distributing pipe is so adjusted that the air enters into the air-distributing canals *s*, *Fig. 1*; thence by small openings *t* in the arch into regenerator *R*, where it is heated and then by slits *u* also enters into bottom canal *h*. In this bottom flue the combustion takes place. The hot products of combustion ascend by the vertical flues of the side walls into horizontal flue *e*, and descending pass through the vertical flues of the other half into bottom section *i*, and from there by slits *a* into regenerator *R'*, heat the canal, pass by the small openings *t'* into canals *s'*, and from here by the adjusting trap into the chimney. After a certain time the adjusting traps are reversed and the gas take a reversed course. Originally it was intended (and also executed by the first plants) to heat the air and also the gas by a second regenerator, located at each end of the ovens. This second regenerator has been abandoned, for it was considered more important to heat the ten times greater quantity of air to a high temperature than to heat also a comparatively small quantity of gas and besides to risk dangerous explosions.

In all later plants there is only one regenerator on each side of the ovens, shown by the accompanying drawings, and the Otto-Hoffmann oven has been simplified considerably by this device and without impairing its efficiency.

The air is heated in the regenerator to about 1,000° C. and it is due to this heating that only a part of the gas is required to heat the ovens, and a considerable quantity is at disposal for other purposes.

I will now try to give a general survey of the arrangements of the condensation plant, shown by *Figs. 3, 4* and *5*.

When the gas generated in the ovens has entered the receiver by the valves it is drawn through the apparatus by exhauster *A*. In this course are inserted several arrange-

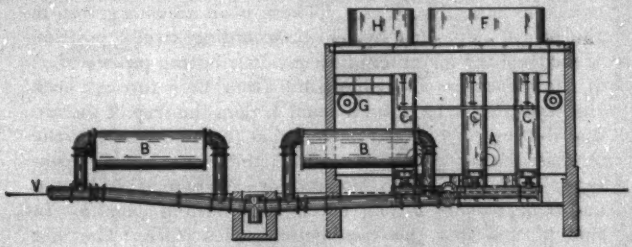

FIG. 4.—Side elevation of condensation plant.

ments, for instance, two coal-dust separators *B* cooled by air, in which the greater part of the tar contained in the gas, and also the coal-dust forced along, precipitate, thus reducing clogging of the apparatus by the latter.

The gas then enters into condensers *C*; square, vertical and riveted boxes in which are fastened a number of wrought-iron pipes through which runs the cool water. The gases ascend around the pipes, while the products of condensation, tar and ammonia water, run off continually at the bottom.

After the gas has passed the coolers it enters into the first scrubbers *D*; these are square and the gas is distributed over a number of pipes which are dipped into water. The gas is first washed in this apparatus by weak ammonia

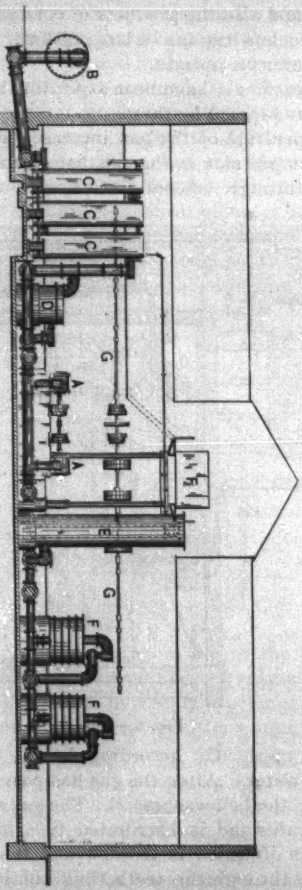

FIG. 5.—Elevation of condensation plant.

water in order to enrich the latter, by which also tar precipitates. The apparatus is so constructed that the water continuously enters at the top and runs off at the bottom.

This water and also the products of condensation of the air and water coolers run into a large cistern, in which tar and ammonia water precipitate.

The exhausters *A* have been aspirating till now and from here the gas is forced by them.

The temperature of the gas increases a few degrees by the rapid compression in the exhausters and, therefore, it is conducted through coolers *E* to lower the temperature

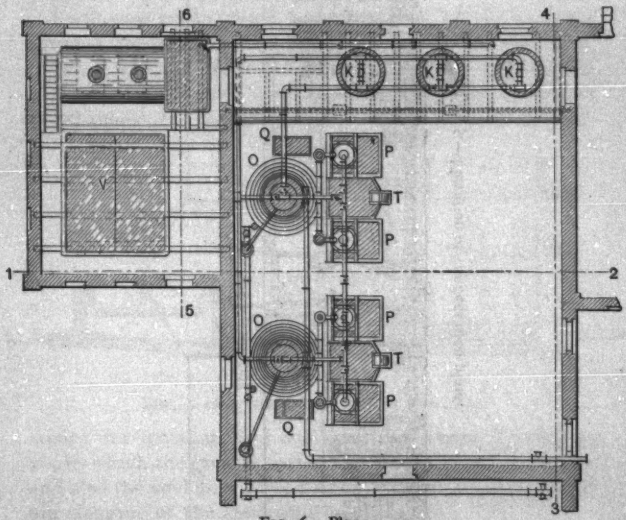

FIG. 6.—Plan.

possibly to 13–18° C., according to the temperature of the cooling water. After the gas has passed the coolers *E* it enters into the bell-washers *F*. The gas enters at the foot of the apparatus and is distributed to a number of bells, the lower rim of which is toothed and immersed in water, and is forced through the teeth, thus coming into intimate contact with the water. The washers contain four to six stories if necessary, and the water flows from above downwards. The gas flows in the contrary direction and is always

forced against the fresh water, by which all the ammonia and the rest of the tar are precipitated completely.

The gas, deprived of tar and ammonia, can now be conducted to the ovens to be consumed, if it should not be prefered to remove other products of the gas, as benzole, which is done by special methods. Quite a number of such plants are in operation, but the operators treat the manufacture of benzole as a secret.

Before the gases from the condensation enter into the distributing pipes g and g' by the adjusting traps, it has to pass a small gas tank, acting as a stand-pipe, to regulate the pressure of the gas, and its principal object is always to show conspicuously to the supervising officer the pressure

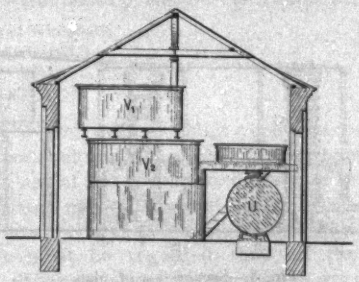

FIG. 7.—Section 5–6 of plan.

of the gas exactly, for the temperature of the ovens can be kept uniform only by maintaining a constant pressure. Temperature measurements by the pyrometer of Steinle & Hartung, controlled by metal compositions, indicated in :

The bottom canal,	1,200° to 1,400° C.
Side walls,	1,100° to 1,200° C.
Regenerators at the beginning of air inlet,	1,000° C.
Regenerators at their ends,	720° C.
Chimney,	420° C.

The tar from the distillation, separated by specific gravity in cisterns is pumped into tank *H*, *Fig. 4*, by a pump located on the wall, driven by shaft *G*, and then it is tapped into tank cars to be shipped to the tar distillation works.

The ammonia water of the cistern is similarly pumped into tank *J*, and from here it is conducted to the apparatus of the ammonia factory.

The ammonia factory has two column apparatus *O*, system Gruenberg-Blum (other factories use the apparatus of Dr. Feldmann with equally good results) each of a capacity of 30,000 litres equal to thirty tons of ammonia water. The water enters at the top of the column, running from column to column downwards. Contrary to the course of the water flows dry steam, by which the ammonia is absorbed and forced along. The ammonia combined with water is dissolved by lime water. The lime water is pumped from lime box *Q* into the apparatus located above the stair column.

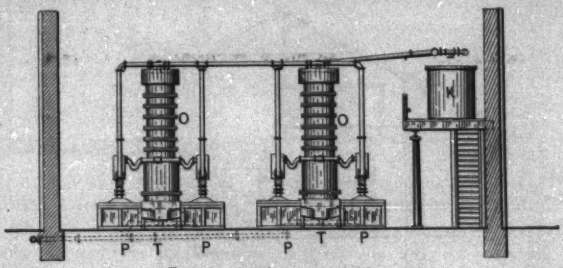

FIG. 8.—Section 3-4 of plan.

The steam saturated with ammonia is conducted either to the boxes *P*, lined with lead into sulphuric acid, and the ammonia and sulphuric acid combine to form sulphate of ammonia, or into coolers *K* to be condensed to concentrated ammonia water.

In order to obtain salt the ammonia fume is conducted to sulphuric acid and when the acid is saturated the salt is brought on the dripping platform *T*.

In order to obtain concentrated ammonia water, the product of condensation of coolers *K* is run into storage *U* of a capacity of about ten tons and thence by air pumps into railroad car tanks.

The sulphuric acid necessary for the manufacture of the salt is furnished by railroad car tanks and stored in tanks *V*,

by means of air pumps and after its settlement it is conducted alternately from *V* and *V'* to tanks *P* by siphons and lead pipes.

The waters from apparatus *O* are conducted to a purifier, where the lime settles and the water runs off pure.

The Otto-Hoffmann ovens with coal distillation are most numerously introduced to-day, and there were in operation in Germany alone:

	Ovens in Operation	*Under Construction.*
1884,	40	120
1885,	120	140
1889,	605	
1891,	1,205	

The Otto-Hoffmann ovens are distributed as follows:

Coal District Westphalia,	470
Silesia,	705
Saar,	30
	1,205

The cost of such ovens is about 5,000 mks. per oven, and 7,000 mks. per oven for rest of the plant, or together 12,000 mks.; or a plant of sixty ovens would require an investment of about 720,000 mks. This cost seems exceedingly high, but the profits are so considerable that it may be ignored. Further, it must be regarded that all the important machinery, exhausters, ventilators, pumps are arranged in duplicate, by which the cost is increased considerably, and also that interruptions of operations are excluded, if a portion of the apparatus should become defective.

The quality of coke from the Otto-Hoffmann oven is a very good one and the gain is higher than from the same coal in common ovens. Formerly the gain from dry coal was about sixty-seven per cent. It is about seventy-five per cent. now, which is accounted for by the fact that the ovens with coal distillation always are closed air-tight, and therefore the combustion of the coal in the ovens cannot take place.

It can be assumed that one Otto-Hoffman oven produces 1,000 cubic metres of gas per day and consumes of these 600 cubic metres, leaving 400 cubic metres for other purposes.

A plant of sixty ovens in Westphalia furnishes a gas surplus of 24,000 cubic metres per day, by which boilers of 375 square metres heating surface can be heated. The condensation would require 140 to 150 square metres, leaving at disposal for other purposes about 230 square metres.

The following figures are from Upper Silesia: production per day 1,150 cubic metres; consumption per oven, 650 cubic metres; gas surplus per 60 ovens per day, 30,000 cubic metres.

Saar District and Westphalia: production per day, 1,000 cubic metres; consumption per oven, 600 cubic metres; gas surplus per 60 ovens per day, 24,000 cubic metres. One hundred cubic metres of gas are equal to 87·5 kilo-

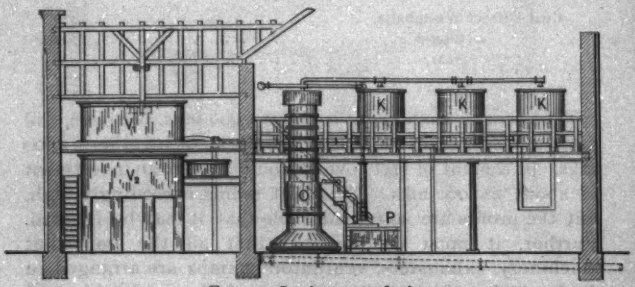

FIG. 9.—Section 1–2 of plan.

grams of coal, or 24,000 and 30,000 cubic metres of gas, respectively, equal to 21,000 and 26,250 kilograms of coal, respectively.

Instead of utilizing the surplus gas for heating boilers it might be used for illumination also, as is done at the Friedenshoffnung and Carl-George-Victor Mines at Gottesberg. A brief calculation of the results of a plant of sixty ovens in Westphalia is given in the following figures: 60 ovens with a distillation process of 48 hours = 30 ovens per day; per month 30 working days = 900 ovens per month. Each oven is charged with 7,100 kilograms of wet coal, containing about 12 per cent. of water, equal to 6,250 kilograms of dry coal.

Per month 900 × 6,250 = 5,625,000 kilograms of dry coal. According to experience, 100 kilograms of dry coal furnish on an average 1·15 kilograms of sulphate of ammonia = 64,687 kilograms per month and 2·75 kilograms tar = 154,687 kilograms per month.

	Mks.
100 kilograms of sulphate of ammonia are worth to-day	
21·00 mks. = 64,687 × 21	= 13,584
100 kilograms are worth 3·50 mks. = 154,687 × 0·035 =	5,424
Receipts per month, ...	19,008

Total expenses:

Wages and other operating expenses, ...	5,700
Gross profits per month, ...	13,308
per annum	159,696

or 2,661 mks. per oven from the by-products only, against an investment of 12,000 mks. per oven or 7,000 mks. for the coal distillation; to which must be added the profits from the manufacture of coke. Interest and redemption are excluded in the calculation.

The results of the plants are more favorable in Upper Silesia, where the gain of sulphate of ammonia is as high as 1·25 per cent. and 4·5 per cent. of tar.

The results of the Saar District are not so favorable, especially in regard to ammonia.

I have mentioned already that the manufacture of benzole is still held as a secret, and I will remark only that the gain of benzole varies between 0·3 and 0·7 per cent. of the dry coal. On account of the fluctuating value of benzole I will give no estimate, as this might not be correct to-morrow.

However, the course of the manufacture of benzole indicates that by and by also other products contained in the gas may be saved, and further developments of this industry are probable.

I must mention that besides the construction described a number of other systems are in operation with satisfactory results; for instance, the considerable plant of Appolt ovens at Florentine Mine, near Lagiewnik, which obtain remarkable results.

Machine Inspector Donders made the first experiments in 1883–84 to save the by-products without heating the air and without deterioration of the quality of coke, and his success led to the erection of the extensive plant referred to.

There were in operation 15,700 coke ovens in Germany in 1891, producing 7,700,000 tons of coke, of which about seventy per cent. was produced in the Ruhr District (Rhineland and Westphalia). The total number of these ovens could produce 110,000 tons of sulphate of ammonia and 275,000 tons of tar of a value of 32,000,000 mks. but only 18,000 tons of sulphate of ammonia and 45,000 tons of tar with a value of 5½ million mks. are produced by the manufacture of coke with coal distillation.

The figures of imports and exports of sulphate of ammonia (Chili nitrates and guano) from 1885 to May last show that the import of sulphate of ammonia since 1885 has not increased, but has decreased slightly, while the export is unimportant. But the import of Chili nitrates has increased enormously from 157,000 tons in 1885 to 396,000 tons in 1891, and to 235,000 tons within the first five months of this year.

The value of imported sulphate of ammonia in	*Mks.*	*Mks.*
1891 is estimated per 100 kilograms, ...	24·00 =	7,466,000
Chili nitrates, per 100 kilograms, ...	17·50 =	69,239,000
Guano, per 100 kilograms, ...	15 80 =	7,865,000

against an export for the same period of:

	Mks.	*Mks.*
Sulphate of ammonia, per 100 kilograms, ...	24·00 =	230,000
Chili nitrates, per 100 kilograms, ...	18·50 =	1,831,000
Guano, per 100 kilograms, ...	16·00 =	444,000

Therefore, 84,065,000 mks. have been sent abroad for nitrates. Furthermore, these figures also show that by the reconstruction of all existing coke ovens of Germany to coal distillations, an overproduction would be excluded, for they could supply only twenty-five per cent. of the demand for nitrates, but 19,000,000 mks. would be saved to the country, and also an additional 8,000,000 mks. for tar.

Although we cannot expect that the total imports of nitrates can be supplied by sulphate of ammonia, the

latest experiments of Professor Wagner at Darmstadt have demonstrated more favorable results, and he was enabled to declare before the last annual meeting of the gas and water experts that, while formerly he did not recommend the universal application of sulphate of ammonia for agricultural purposes, because manuring with Chili nitrates warranted results with more safety, he was now prepared to advise the farmers to its universal application, for he could state the conditions by which favorable results of different soils and plants could be obtained with safety.

It is not to be apprehended that with the application of sulphate of ammonia the increased production would be accompanied by reduced prices, for the value of nitrates is regulated by the world's markets.

The development of the tar industry is a continuous one and its rapid extension is of much importance for coal mines, for it will supply them with pitch for the manufacture of briquettes from coal otherwise hardly marketable. According to *Glueck Auf* and the *Mine and Factory Gazette*, the consumption of pitch for the manufacture of briquettes is 150 tons per day, which would require 300 tons of tar, while the coke ovens in operation furnish about one-half of this, and the manufacture of briquettes certainly will be increased.

You will conclude from my address that the saving of by-products simultaneously with the manufacture of coke is of importance, not only for the coal and iron industry, but also of the highest importance from a politico-economic standpoint, and therefore its further development should be encouraged to the utmost.

REMARKS ON THE CHANGING OF THE PHYSICAL PROPERTIES OF COKE MADE IN THE BY-PRODUCT OVENS.

BY JAMES J. FRONHEISER.

The greatest fault found in Europe, and more particularly in England, with the coke made in the by-product ovens, was on account of its greater softness, in consequence of which, at the proper temperature, too much of it was wasted in the upper part of the blast furnace by being dissolved, as it were, by the escaping carbonic acid, thus: $CO_2 + C = CO$. (See *Journal of the Iron and Steel Institute*, of 1885, vol. i, p. 7.)

On p. 287 of Sir I. Lowthian Bell's *Manufacture of Iron and Steel*, we find the following:

"Hard coke, soft coke and charcoal pounded as near as possible to the same size were placed in a hard glass tube which they filled, and were then raised to a good, red heat in a Hofman's double furnace. During the space of thirty minutes, 800 cc. of carefully dried carbonic acid was passed over each specimen. The issuing gases had the following volumetric composition:

	Hard Coke.	*Soft Coke.*	*Charcoal.*
Carbonic acid, ...	94·56	69·81	35·2
Carbonic oxide, ...	5·44	30·19	64·8
	100·00	100·00	100·00"

Now, in order to correct the bad properties of soft coke, we recently tried some experiments with the same kinds of coal (Connellsville), coked it in a bee-hive oven under different conditions, and found by submitting the resulting coke to the same conditions used by Mr. Bell, the following results:

	Prepared Coke.	*Ordinary Coke.*	*Charcoal.*
Carbonic oxide, ...	8·72 cc.	43·76 cc.	217· cc.

Proving that under certain conditions the same coal can be treated so as to furnish harder coke than by the ordinary

treatment, thereby overcoming the disadvantages charged to the coke made in the by-product ovens.

This process has recently been patented by C. S. Price, General Manager, and James J. Fronheiser, Superintendent of Laboratories of the Cambria Iron Company.

THE HELIOCHROMOSCOPE.

BY F. E. IVES.

[*Read at the stated meeting of the Institute, held Wednesday, Oct. 19, 1892.*]

Mr. JOS. M. WILSON, President, in the chair.

MR. IVES:—It was in 1888 that I first described and demonstrated, at the Franklin Institute, a method of reproducing the natural colors by photography, which differed in certain vitally important particulars from somewhat similar processes which had already been carried out by Cros and Du Hauron in Paris, Albert in Munich, Bierstadt in New York, and others. I succeeded in reproducing the natural colors in landscapes and various objects with a degree of accuracy which I have good reasons to believe had never before been approached by any method without the intervention of the artist's brush. The procedure was, however, too complicated and difficult for profitable commercial application, and comparatively few specimens were made.

I now present to your notice devices which so greatly simplify the operation of the process as to make it quite possible to place it in the hands of even the "press-the-button" class of amateur photographers, and yet yield results that are no more defective in color rendering than the ordinary photograph is in the rendering of monochrome light and shade.

The first of these devices is a camera attachment, by means of which the three pictures representing the effect upon the three fundamental color sensations are made by a single exposure on a single sensitive plate, and from a single point of view. The device as now perfected is surprisingly simple, being comprised in a small box, which

may be attached to the front board of an ordinary camera. The division of the light ray is effected by transparent mirrors, as in some of my earlier cameras, but in such manner as to dispose the images symmetrically on a single plane, without altering the position of the camera in relation to the object.

FIG. 1.—The Heliochromoscope.

The second device, which I call a heliochromoscope, contains the same arrangement of mirrors, turned about so as to serve to re-combine the three photographs in such manner that the photographic color record is translated into color again as readily as the sound record in the phonogram is translated into sound in the phonograph.

The most important advantage of this device is that it may be used at any time, at a minute's notice, like the stereoscope; and, as almost everybody may possess one, it is competent to make the realization of color photography a household affair. It also more completely fulfils the theoretical conditions of success than either the production of color prints or lantern projections, and produces an illusion of nature more correctly than would be possible with even an absolutely perfect color print on paper, because the picture is seen without surface reflections or distracting surroundings.

I claim for this system of color photography that it is perfectly rational and scientific, and a true solution of the problem of reproducing the natural colors in a photographic picture. This claim meets with a good deal of opposition in the minds of some people, whose mental attitude is a source of wonder to me, because the same sort of objections that are made to the triple photograph would apply to the stereogram and the phonogram. One is an automatic record of color, another of binocular vision, and another of sound; each must be placed in a special device in order to reproduce that which it has recorded—the triple photograph or chromogram into the heliochromoscope, the stereogram into the stereoscope, and the phonogram into the phonograph. I do not remember ever to have heard the stereogram denounced because it is not a single print with embossed relief, or the phonogram because it has no vocal cords.

Some even go so far as to deny that this can properly be termed color photography at all, although the same individuals are in the habit of calling pictures that cannot be made to show colors "orthochromatic" or correct-color photographs. But the most extreme illustration of this peculiar attitude of mind that I have seen is the assertion of one who, if I am not mistaken, has aspired to be the historian of photography, that this is merely "looking at ordinary photographs through bits of colored glass!" To be consistent, this writer should describe the stereogram as "two ordinary photographs, mounted on the same

card," and the phonogram as a "wax cylinder having a roughened surface like an ordinary file." I believe he did recently write a history of photography, with "an introduction to its latest developments," without once mentioning color-sensitive plates.

I speak of this kind of criticism because it comes from

FIG. 2.—The Heliochromoscope.

men whose writings are in demand, and proves the existence of a deep-seated prejudice, which I have encountered in the development of other applications of photography, and which must be combated in order to overcome it. I will give an illustration: When, in 1880, I succeeded in realizing a mechanically accurate and practicable method

of half-tone block-making, I could find only one engraver who believed there was a future for processes that rendered the shading in equally spaced graduated lines and cross-lines. Engravers, printers, publishers and photographers were agreed that if a block be made up of lines, those lines must follow the contours of the object depicted, as in the conventional wood engraving. Since that could not be done, a grain, similar to the well-known lithographic grain, must be substituted for the line tint. I declared that the objection to a regularly lined tint was a prejudice, stuck to it, and already, within twelve years, plates having that same lined tint have come into such extensive use as to replace millions of dollars' worth of wood engravings. They are used in illustrating books and periodicals of the highest class, and the advantages of the mechanical-lined tint are such that it threatens even to invade the domain of photogravure. Mr. Louis E. Levy exhibited such results at the last monthly meeting of the Franklin Institute, and I myself applied for a patent on a printing plate of this character more than a year ago, having first experimentally demonstrated certain important advantages which they can be made to possess.

We did not make half-tone printing plates of the kind that engravers and printers and publishers thought they must have, but they have concluded to take what we did make, and are taking them more and more every year.

We have not made photographs in the natural colors of exactly the kind that people have been looking for, and there is good reason to doubt if such a result will ever be accomplished by a simple process; but we have actually realized, by a process almost as simple as stereoscopic photography, results better than can even be hoped for in color prints, and so perfect that they must ever represent the standard which results by any other method must be made to approach in order to be acceptable. A great many people seem to think that this is not what they want; but I have quite as much faith in the future of the heliochromoscope as I ever had in the future of half-tone block-making

in line. It has been a revelation to me, and I believe it will be to the whole world.

I met a professional artist in London, a clever painter of both portraits and landscapes, who spent what seemed to me a very long time studying a bouquet of English flowers reproduced in the heliochromoscope, and left it only to return to it again and again, as if it fascinated him. At last a friend asked him for an expression of opinion upon the merits of the device. After some hesitation, he said that he had attended one of my lectures at the Royal Institution, expecting to go away and report the failure of another attempt to reproduce the natural colors by photography. He had not been able to do so, but was forced to confess that color photography is a fact. The demonstration was conclusive to him. The heliochromoscope will have no better friends than the artists, for whom it will not only reproduce nature, but the masterpieces of art as well, in such manner that they can be studied in far-distant lands almost as well as in the galleries where they repose.

In the far West, I met the representative of a large New York firm of importers of Oriental rugs. He assured me that he was ready to pay $100 out of his own pocket for a duplicate of the heliochromoscope that I showed him, with a set of photographs of the rugs that he carried about with him only to show their colors. It would save his firm a great deal of money that went in expensive sample rugs, and in cost of extra baggage, and it would save him a great deal of trouble. A professional house decorator spoke much to the same effect. Evidently, the heliochromoscope will have many fields of usefulness—so many, perhaps, that its function as a source of drawing-room entertainment, for which alone many have supposed it to be adapted, will prove of secondary importance. But I shall be greatly surprised if, even for the latter purpose, it does not become more popular than the stereoscope ever was, although it is necessarily a much more expensive instrument

I have said that this system of photography is capable of giving reproductions that are no more defective in color

rendering than the ordinary photographic process is in the rendering of monochrome light and shade. Not to be misunderstood, let me say that no photographic process is capable of reproducing even monochrome light and shade with strict accuracy. The most correct negative-making process will exaggerate contrasts in the middle shades of the picture at the expense of the two ends of the scale. The same defect necessarily appears in the color process, making colors too pale in the light shades and too dull in the dark shades, with slight exaggeration of contrasts in the middle shades. This defect would not generally be noticed by most persons, and it would not be fair or reasonable to count it against this process any more than it is counted against ordinary photography.

The most serious practical difficulty encountered in the operation of the process is due to unevenness, often slight, in the coating of the sensitive plates. Unevenness that would not be noticed in ordinary negative work often seriously affects the result in this process. This difficulty can be readily overcome by the plate-makers; but it will not pay them to make the necessary changes until there is a considerable demand for plates for this work, and then they will be obliged to charge more for them than they now do for the ordinary plates. With such sensitive plates as I would ask for, and know that it is quite possible for the plate-makers to provide, the average results by this process should be better than the best that I have shown.

The subject now in the heliochromoscope is a bouquet of Yellowstone Park wild flowers, gathered by Mr. Jennings. We placed it in a pitcher borrowed from the dining-room of the Lake Hotel and photographed it in our bed-room. You will see the bouquet as it would appear by gaslight, because I am using gaslight as a source of illumination. By daylight, the colors are exactly as they appeared to us when we photographed it.

HAINES AUTOMATIC MICROMETER GAUGE, FOR GAUGING EITHER HOT OR COLD ROLLING MILL WORK TO EXACT THICKNESS WHILE IN THE ACT OF ROLLING.

By R. B. Haines, Jr.

[*Read at the stated meeting of the Institute, November 16, 1892.*]

Mr. Jos. M. Wilson, President, in the chair.

Mr. Haines:—The automatic micrometer gauge was designed to meet the demand for more accuracy in rolling sheet, bar or plate metal to exact thickness than has heretofore been obtained by the ordinary fixed or caliper gauges. It was specially designed for gauging hot work while in the act of rolling, so that the roller might know, at each pass of the metal through the rolls, the exact amount of reduction and what adjustment are necessary for the succeeding pass and finally to finish the work to the proper thickness. In rolling such material as boiler-, ship- or tank-plate, this is particularly important. The rolls cannot be set as in a rail mill, where large quantities of duplicate pieces are turned out, but must be adjusted constantly for each plate rolled. One plate is to be finished three-eighths of an inch thick, the next one-fourth of an inch, the following 1·13 inches, the next one-half inch, and so on. This applies as well where a large number of plates of the same thickness are required, as the rolls must be opened wide enough to receive the bloom or ingot, then are gradually closed together while the bloom is passed backward and forward between them till the desired thickness is reached. In modern mills there is an indicating attachment connected with the large housing screws (for closing the rolls together), that will show how much the bloom is being reduced by each pass, and will give an approximate idea when the plate is reduced to the proper point, but it can never be relied on to determine the exact amount required

for the finishing pass, as it will not measure the compression of the screws and bearings, the springing of the rolls, or make allowance for the extra diameter caused by heating. Hand gauges must, therefore, be used to make this determination. The instrument in common use is the fixed or caliper gauge, and just herein lies the difficulty in getting accurate work. Take, for instance, the plates for a marine boiler. These are usually of large size, a single one often weighing 6,000, 8,000 or 10,000 pounds, and gauging (say) seven-eighths, one and one-thirty-second or one and one-half inches. They are calculated by the engine designers to a certain thickness, in order to carry a suitable pressure for the engines. Should they fall below this thickness, the safe working pressure is cut down for every one-hundredth of an inch under the gauge; if the plates should be over the calculated thickness, the purchasers object to the excess of weight. In either case allowances must be made, or the material is rejected, both of which are undesirable. In making these plates suppose a common fixed caliper gauge is used. The roller, judging by experience when the plate is nearly down to thickness, tries the gauge on it. One of three things happens: either the gauge will not go on the plate, or it will go on just right, or else will go on too loosely. If it goes on too loosely the mischief is done. If it fits just right the point is gained, but when the gauge will not go on the plate, there is yet a chance to make it right or spoil it. To make it right another pass is necessary and a definite knowledge of the amount of reduction required is of vital importance. With the fixed gauge this is mere conjecture. It may take two or three passes of very slight reduction each, but that takes time and there is still a risk of going too far, whereas, if the exact amount were known, one pass would have sufficed. The need to determine definitely this unknown quantity led to the invention of the automatic micrometer gauge. Heretofore it was hardly necessary to work to such close measurements, but the tendency of the present time along all lines is toward greater accuracy, and what would have passed, a short time ago, is rejected to-day. The automatic microm-

eter gauge is somewhat similar in general character to a micrometer caliper, but the construction is different, as the conditions of use are not at all similar. The gauging screw is made with coarse pitch and double thread, and has for a head a graduated disc about two and one-half inches in diameter, which indicates the measurements. The edge of this disc is serrated and can be clamped or held at any point, to prevent turning, by a locking bar or knife edge arranged to slide in between the teeth at the will of the operator. The movement of this locking bar is controlled by a trigger (on the gauge handle), operated by the fore-finger. The handle is made of sufficient length to enable the person using it to measure hot work with ease. Fastened to the gauging screw, directly under the disc, is a spiral spring which tends to rotate the disc, and thus close the screw upon any article to be measured. In practical working, for instance in gauging a hot plate, the dial is turned by hand (to open the gauge screw) considerably more than the finished thickness of the plate; the gauge is then put on the plate and the trigger pulled. The spiral spring causes the disc to revolve and sets the gauge screw on the surface of the plate. The trigger is now released and the locking bar engaging the teeth of the disc prevents it from turning while the gauge is pulled off the plate to take the reading. The graduations on the face of the disc indicate the thickness. This can be repeated at each pass through the rolls and will show the amount of each reduction. In following the work down in this manner, the exact amount of reduction for the finishing pass will be determined. The whole operation is extremely simple, yet gives the gauger at all times, definite measurements that show at each step just what is being done. The gauge weighs about two and one-fourth pounds. It is operated altogether with one hand, excepting when set for the first time for each plate.

A single one replaces all the fixed caliper gauges for standard thickness (within its range), and obviates entirely the expense of making special gauges for special thicknesses. In our own work we seldom roll plates less than three-six-

teenths of an inch thick, and between that and one and one-half inches which is about the heaviest. We formerly used thirty-three caliper gauges, besides frequently making special tools for odd sizes.

These we have now discarded and use in place of them three of the automatic micrometer gauges.

We have had them in use for several months and the result shown in the increased accuracy of the work is very satisfactory.

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

By Emrick A. Werner.

[*Continued from vol. cxxxiv, p. 448.*]

II

Suspension Bridge with Parabolic Line of Thrust and Triangular Stiffening Truss.

x	y	f	$\frac{y}{f}$	$\tan \mu$	$\cos \mu$	
15	10·8		0·36	$\frac{10·8}{15} = 0·72$	0·811	$\tan \mu_4 = \frac{30}{33} = 1·10$
30	19·2		0.64	$\frac{6·4}{15} = 0·56$	0·872	$\cos \mu_4 = 0·671$
45	25·2	30·0	0·84	$\frac{6·0}{15} = 0·40$	0·928	$\tan \alpha = \frac{17·5}{15} = 1·17$
60	28·8		0·96	$\frac{3·6}{15} = 0·24$	0·972	$\cos \alpha = 0·651$
75	30·0		1·00	$\frac{1·2}{15} = 0·08$	0·996	

$$\tan \mu_{m+1} - \tan \mu_m = 0·16$$

$$h = 17·5$$

One hundred and fifty foot span, ten panels, fifty feet each thirty-foot rise.

The thrust is taken up fully by the cable, which has thus

the form of the line of thrust. As stiffening truss is used a triangular truss of 17·5 depth. The dead load is assumed to 26,000 pounds per panel point — 14,000 pounds acting at

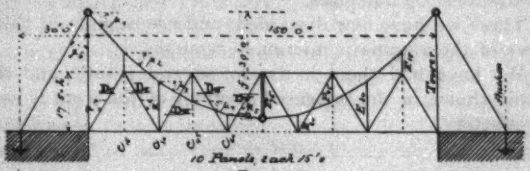

FIG. 31.

the bottom chord, 4,000 pounds at the top chord and 8,000 pounds at the cable.

The moving load are the two engines, followed by 3,000 pounds per foot of the track, shown in *Fig. 1.*

The above diagram gives all the data of calculation.

Horizontal Stress in the Cable.—Line of thrust, loading, span and rise being the same as in example *I*, the reactions will be the same as in the upright arch.

$$Max.\ H = 378{,}500$$

$$Min.\ H = 0$$

Vertical stress in the suspension rods E.

$$E\ max. = H\ max.\ (tan\ \mu_{x+\Delta x} - tan\ \mu_x) = 0{\cdot}16 \times 378{,}500 =$$

$$= 60{,}600 \text{ pounds.}$$

$$E\ min. = 0$$

($Tan\ \mu_{x+\Delta x} - tan\ \mu_x$) is constant in the parabola, hence the vertical stress is the same in all rods.

Horizontal stress in the chords.

As no thrust is taken up by the chords, both chords have the same general equation as the upper chord of the upright arch, and

$$\left(\frac{M}{h}\right)$$

reaches its maximum and minimum, as shown there.

Maxima (moments positive):

$$C_{15} = \left(\frac{M}{h}\right)_{15} = 79{,}300$$

$$D_{\mathrm{I}} = +\,79{,}300$$

$$C_{30} = \left(\frac{M}{h}\right)_{30} = 108{,}200$$

$$D_{\mathrm{II}} = +\,36{,}400$$

$$C_{45} = \left(\frac{M}{h}\right)_{45} = 103{,}900$$

$$D_{\mathrm{III}} = +\,45{,}000$$

$$C_{60} = \left(\frac{M}{h}\right)_{60} = 62{,}600$$

$$D_{\mathrm{IV}} = -\,30{,}200$$

Minima (moments negative):

$$C_{15} = \left(\frac{M}{h}\right)_{15} = -\,71{,}500$$

$$D_{\mathrm{I}} = -\,71{,}500$$

$$C_{30} = \left(\frac{M}{h}\right)_{30} = -\,104{,}000$$

$$D_{\mathrm{II}} = -\,32{,}500$$

$$C_{45} = \left(\frac{M}{h}\right)_{45} = -\,99{,}700$$

$$D_{\mathrm{III}} = +\,3{,}300$$

$$C_{60} = \left(\frac{M}{h}\right)_{60} = -62{,}100$$

$$D_{\mathrm{IV}} = +\,35{,}200$$

Horizontal stresses D in the diagonals.

As the depth h of the stiffening truss is constant, these values will be different from those of the upright arch.

$$D_{\mathrm{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{0} = \left(\frac{M}{h}\right)_{15} = [0{\cdot}72\ W_1 g_1 + \\ + W_2 (15 - 0{\cdot}28\ g_2) - 0{\cdot}08\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_{II} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15}$$

$$\left(\frac{M}{h}\right)_{30} = [0{\cdot}48\ W_1 g_1 + W_2(30 - 0{\cdot}52\, g_2) - 0{\cdot}12\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$\left(\frac{M}{h}\right)_{15} = [0{\cdot}72\ W_1 g_1 + W_2(15 - 0{\cdot}28\, g_2) - 0{\cdot}08\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_{II} = [-0{\cdot}24\ W_1 g_1 + W_2(15 - 0{\cdot}24\, g_2) - 0{\cdot}04\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_{III} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = [-0{\cdot}20\ W_1 g_1 + W_2(15 - \\ - 0{\cdot}20\, g_2)] \frac{1}{17{\cdot}5}$$

$$D_{IV} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = [-0{\cdot}16\ W_1 g_1 + W_2(15 - \\ - 0{\cdot}16\, g_2) + 0{\cdot}04\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_V = \left(\frac{M}{h}\right)_{75} - \left(\frac{M}{h}\right)_{60} = -\left(\frac{M}{h}\right)_{60}$$

Maxima.—

$$D_I\ max. = \left(\frac{M}{h}\right)_{15} max. = 79{,}300$$

D_{II} *max.*

$$\text{Maximum line } g_m = \frac{1{,}500}{24} = 62{\cdot}5$$

Max. span = space from (30) to (62·5)

a and *c* being negative.

$$\frac{d\,D}{d\,g} = -a\,(w) + \beta\, W_2 + \frac{w}{\Delta x}[a\,x - (k - \beta x)]$$

$$= +0{\cdot}24\, w + 0{\cdot}24\ W_2 - w$$

introducing

$$w + W_2 = W = \text{total load.}$$

$$\frac{d\,C}{d\,g} = 0{\cdot}24\ W - w$$

First wheel 17·75 from Abutment A, last tender wheel 85·25 from Abutment B.

$$D_{II} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = (1{,}553 - 738)\,\frac{1}{17{\cdot}5} = 46{,}600 \text{ pounds.}$$

D_{III} *max.*

$$\text{Max. line} = \frac{1{,}500}{20} = 75$$

Max. span = space from (45) to (75)

a and c being negative.

$$\frac{d\,D}{d\,g} = + 0{\cdot}20\ W - w$$

First wheel 37·0 from Abutment A, last tender wheel 66·0 from Abutment B.

$$D_{III}\ max. = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = [370 - (187)] \div 17{\cdot}5 =$$

$$= + 31{,}800$$

Note.—The general equation of D_{III} having no member $W_3\,g_3$, the absolute value of D_{III} is independent of any load on W_3.

Check.—The same loading as above, with the addition of the second engine in W_3.

$$D_{III} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = [-558 - (-1{,}115)] \div 17{\cdot}5\tfrac{1}{2} =$$

$$= + 31{,}800$$

D_{IV} *max.*

$$\text{Max. line } g_m = \frac{1{,}500}{16} = 93{\cdot}75$$

Max. span = space from (60) to end of truss.

a being negative.

$$\frac{d\,D}{d\,g} = 0{\cdot}16\ w + 0{\cdot}16\ W_2 + 0{\cdot}04\ W_3 - w$$

or

$$w + W_2 = W_1$$

$$= [0{\cdot}16\ W_1 - w] + 0{\cdot}04\ W_3$$

First wheel 52·0 from Abutment *A*, third wheel of second tender 1·5 from Abutment *B*.

W_1 and w change, the dividing line being in (60).

$$D_{IV}\ max. = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = [-627 - (-1{,}485)] \div$$

$$\div 17{\cdot}5 = 49{,}000$$

$$D_V\ max. = -\left(\frac{M}{h}\right)_{60} = -62{,}600$$

Minima.—

$$D_I = \left(\frac{M}{h}\right)_{15}\ min. = -71{,}500$$

D_{II} *min.*

Maximum line $g_m = 62{\cdot}5$

Minimum span = spaces corresponding to negative a, c and $(\frac{l}{2} - g_m)$ = space from (0) to (45) and from (62·5) to end (150).

FIG. 32.

$$\frac{d\,D}{d\,g} = -a(W_1 + w) + \beta W_2 + c W_3 + \frac{w}{\Delta x} \times$$

$$\times [a x - (k - \beta x)]$$

introducing

$$W_1 + w + W_2 = W_I$$

$$= [0{\cdot}24\ W_I - 0{\cdot}04\ W_3] - w$$

W_1 and W_3 change, as dividing line = top hinge.

Note.—$W_1 g_1$ must be a maximum, hence a load in (15).

$$D_{II} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = [-900 - (-268)] = 17{\cdot}5 =$$

$$= -36{,}100 \text{ pounds.}$$

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, December 20, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 20, 1892.

Dr. Wm. H. Wahl, President, in the chair.

The special business of the evening being the election of officers for the coming year, this matter was considered first.

Letters from the various candidates were read, accepting or declining their nominations made at the November meeting. The gentlemen accepting nominations were Dr. Wm. H. Greene for President, Mr. Henry Bower and Dr. D. K. Tuttle for Vice-Presidents, two to be elected.

The nominees for the remaining offices were the present incumbents, Wm. C. Day, Secretary; Dr. H. W. Jayne, Treasurer, and Dr. Wm. H. Wahl, Conservator.

The Secretary was directed to cast the vote of the Section for all the candidates above-named.

Mr. H. Pemberton, Jr., nominated Mr. Geo. P. Tucker, of the Patent Office, Washington, D. C., and Dr. Wahl nominated Mr. W. J. Williams, of Wilmington, Del.

The Committee on Admission having considered the candidates presented, declared them elected members of the Section.

The annual report of the Treasurer was read and referred to the Auditing Committee, who examined the accounts, and the report was accepted.

The Secretary's annual report was read and accepted.

The committee in charge of the reception tendered, on the 5th inst., to Dr. H. W. Wiley, of Washington, D. C., made a report, which was accepted with a vote of thanks and the committee was discharged.

The Secretary suggested that the interest of our meetings might be increased if during the year we could secure a limited number of papers, giving in condensed form an account of the development of certain subjects either of technical or purely scientific import, thereby showing the present state of knowledge of those subjects. At the suggestion of Dr. Jayne, the matter was referred to a committee to be named by the Chair to consider the advisability of the suggestion and to formulate a plan for carrying it out. The President appointed Dr. Wm. H. Greene, Mr. H. Pemberton, Jr., and

the Secretary members of this committee, with instructions to report at the January meeting.

Dr. S. C. Hooker read a paper on "Di-brom β-Lapachone: its Preparation and Properties." The paper was the joint production of Dr. Hooker and Mr. A. D. Gray.

Dr. Hooker read also an abstract from the "Annual Report of the Secretary of Internal Affairs of Pennsylvania, Department of Industrial Statistics." This abstract treated of the progress of the process of sugar refining as at present conducted at the Franklin Sugar Refinery of Philadelphia. The article showed clearly and in detail the high state of perfection to which the sugar refining industry has been brought.

Both papers called forth considerable discussion from the members present.

Specimens of the substances discussed in both papers were presented for inspection.

A paper on "Artesian Wells as a Water Supply for Philadelphia," by Prof. O. C. S. Carter, of the Central High School of Philadelphia, was submitted by Dr. Greene; it was read by title and referred for publication.

The Section then adjourned. WM. C. DAY, *Secretary.*

THE DEPOSITS OF NATIVE SODA, NEAR LARAMIE WYOMING.

BY H. PEMBERTON, JR., AND GEO. P. TUCKER.

[*Read at the stated meeting of the Chemical Section, November 15, 1892.*]

Previous to the Civil War, and at a time when the line of civilization extended as far only as the Mississippi River, very little was known of the part of the United States west of that limit. A vast region now comprising many large States was described in the geographies of the day as "the great American Desert." It constituted a part of the prairies or plains, so often mentioned in Cooper's novels. And while the prairies, as a general rule (and particularly in elevations not much above sea-level), are composed of a fertile and rich soil, their character changes as the approach is made to the Rocky Mountains, and when an elevation of 7,000 feet is reached as in Wyoming, the soil and climate resemble somewhat the soil and climate of Nevada and other parts of the Great Basin. On this high Wyoming

plateau, particularly in the neighborhood of the town of Laramie, one drives for miles over a perfectly flat country, with nothing but some distant hills to break the wide circle of the horizon—not even a single tree. A little thin grass grows in the gravelly soil, but no other form of vegetation, except when aided by irrigation. The region is nearly rainless, the relative humidity quite low, and all conditions favorable to the formation of the saline deposits peculiar to this portion of the United States.

About fourteen miles southwest of Laramie, there exists a deposit of sulphate of soda, such deposits are locally known as "lakes." The deposit in question is composed of three of these lakes lying within a stone's throw of one another. They have a total area of about sixty-five acres, the local names of the three being the Big Lake, the Track Lake and the Red Lake. They are the property of the Union Pacific Railroad Company, are connected by a branch of that road with the main line at Laramie, and are generally known as the Union Pacific Lakes.

In these lakes the sulphate of soda occurs in two bodies or layers. The lower part constituting the great bulk of the deposit, is a mass of crystals of a faint greenish color, mixed with a considerable amount of black slimy mud. It is known as the "solid soda." We give an analysis of this below.

ANALYSIS OF SOLID SODA IMMEDIATELY UNDER THE TOP LAYER OF WHITE SULPHATE OF SODA ON RED LAKE AND TRACK LAKE (U. P. LAKES).

	Anhydrous. Per Cent.	*Crystallized. Per Cent.*
Na_2SO_4,	36·00	81·63
$CaSO_4$,	1·45	1·82
$MgCl_2$,	·77	1·64
NaCl,	·21	·21
	38·43	85·30
Insoluble residue (at 100° C.),		13·86
		99·16

Total chloride calculated as NaCl equals 1·16 per cent.

This calculated on 100 parts anhydrous: Na_2SO_4 equals 3·22 per cent. NaCl.

This solid soda is stated to have a depth of some twenty or thirty feet. Borings were made a number of years ago under the direction of the Union Pacific Railroad agents, but all attempts to obtain the results of the same were futile, as the records have been mislaid or lost. There is nothing to prove that the depth is not shallower than stated above.

Above the solid soda occurs the superficial layer of *pure white crystallized sulphate of soda.* This is formed by solution in water of the upper part of the lower body—the crystals being deposited by evaporation or by cooling, or by the two combined. A little rain in the spring and autumn furnishes this water, as do also innumerable small, sluggishly flowing springs present in all the lakes. But on account of the dry air of this arid region, the surface is generally dry or nearly so, and in midsummer the white clouds of efflorescent sulphate that are whirled up by the everblowing winds of Wyoming can be seen for miles. Even should there be a little water present, there is no difficulty in gathering the crystals by the train load. The spring, however, is the worst season of the year, on account of the warm weather and of the rains—conditions unfavorable to the formation of crystals. The layer of this white sulphate is from three to twelve inches in thickness. When the crystals are removed, the part laid bare is soon replenished by a new crop.

The following is an analysis of the purest of this white sulphate of soda, calculated upon an anhydrous basis: that being the condition, of course, in which it would be used.

Na_2SO_4	99·73
$MgCl_2$	·26
Insoluble	trace
	99·99

Several hundred tons of this have been shipped by the railroad to the works at Laramie City. The plant there for dehydrating the crystals is not of the best, and the long exposure to the dust and smoke of the fire gases in the evaporation—and again in the calcining—introduces more

or less impurity into the finished calcined sulphate of soda. The following is an analysis of the latter:

	Finished Calcined Sulphate of Soda. (From U. P. Lakes.)	
Na_2SO_4,	95·80	soluble in water.
$CaSO_4$,	·76	
NaCl,	1·84	
Ignition,	·19	insoluble in water.
SiO_2,	1·48	
Fe_2O_3,	·06	
Al_2O_3,	·31	
CaO,	·20	
MgO,	·44	
	101·08	

This analysis represents the general run of the sulphate, as manufactured in Laramie. The sample was taken from a carload lot sold to the Wyoming Glass Company. It contains only a trace of iron, and, of course, no free acid.

At the time when we examined these lakes, in 1888, they were entirely under water. An irrigating canal—or "ditch"—had been located within a half mile of them, the water from which had gradually collected to the extent of several feet in the lakes. The course of the canal has since been changed, and the lakes are again in about their normal condition.

Samples of this water were collected by us, and analyzed as giving a very fair idea of the average composition of the deposits. The ingredients are calculated to the anhydrous condition. The last item, it will be noticed, is given as anhydrous borax, $Na_2B_4O_7$. It represents the results of titration with standard acid, using methyl orange as an indicator. It may be noted that, on account of the lime salts present in solution, alkaline carbonates and phosphates must be absent, and direct test proved the absence of soluble silicates. We have noticed the same titration reaction (if we may so call it) in a sample of sulphate of soda from a deposit near Rawlins, Wyoming, and, in general, it may be stated that the character of the climate, soil, and formation in Wyoming is very similar to that of such parts of the Pacific Slope as are known to contain deposits of borax.

WATER FROM BIG LAKE (U. P. LAKES).

Density = 9¾° Tw. (= 1·0487 sp. gr.)

10 cc. contains:

	Grams.	*Per Cent.*
Na_2SO_4,	0·4490 =	81·43
$CaSO_4$,	0·0175 =	3·17
$MgSO_4$,	0·0060 =	1·09
$MgCl_2$,	0·0643 =	11·66
$Na_2B_4O_7$?	0·0146 =	2·65
Total solids,	0·5514	100·00
(Total solids by evaporation,	0·5417)	

One cubic foot contains $6\frac{88}{100}$ pounds of pure crystallized sulphate of soda.

WATER FROM TRACK LAKE (U. P. LAKES).

Density = 14½° Tw. (= 1·0725 sp. gr.)

10 cc. contains:

	Grams.	*Per Cent.*
Na_2SO_4,	0·7563 =	92·23
$CaSO_4$,	0·0146 =	1·79
$MgSO_4$,	0·0070 =	·85
$MgCl_2$,	0·0300 =	3·66
$Na_2B_4O_7$?	0·0121 =	1·47
Total solids,	0·8200	100·00
Total solids by evaporation,	0·8240	

One cubic foot of this water contains $10\frac{72}{100}$ pounds of pure crystallized sulphate of soda.

WATER FROM RED LAKE (U. P. LAKES).

Density = 17¾° Tw. (= 1·0887 sp. gr.)

10 cc. contains:

	Grams.	*Per Cent.*
Na_2SO_4,	0·9307 =	91·77
$CaSO_4$,	0·0201 =	1·98
$MgSO_4$,	0·0143 =	1·41
$MgCl_2$,	0·0416 =	4·10
$Na_2B_4O_7$?	0·0075 =	·74
Total solids,	1·0142	100·00
Total solids by evaporation,	1·0320	

One cubic foot of this water contains $13\frac{19}{100}$ pounds of pure crystallized sulphate of soda.

We give, also, below analysis of sulphate of soda from lakes controlled by Col. S. W. Downey, of Laramie. Of these deposits we know but little other than that they are situated about twenty-five miles southwest of Laramie, and as indicated by the analyses, are contaminated by lime and

magnesia salts to a considerable degree. Both analyses were made on samples previously calcined.

	S. W. Downey's Wilcox Lake.	*S. W. Downey's Red Soda.*
Na_2SO_4,	43·12	69·55
$MgSO_4$,	41·70	6·75
$CaSO_4$,	—	11·24
NaCl,	·20	1·01
Ignition,	·32	·33
Insoluble,	16·15	10·50
	101·49	99·38

From a commercial standpoint these Wyoming deposits are interesting, inasmuch as they furnish cheaply and in large quantities quite a pure grade of sulphate of soda. This sulphate being free from iron, and also, of course, from free acid, is well adapted to use in the manufacture of glass. Freight rates from the East are in its favor and allow a price that should yield a fair profit. Attempts have been made at Laramie on quite an elaborate scale, to manufacture soda ash and caustic by the Leblanc process. These efforts were not remunerative.

ARTESIAN WELLS AS A WATER SUPPLY FOR PHILADELPHIA.

By Oscar C. S. Carter,
Prof. Geology and Mineralogy, Central High School, Philadelphia.

[*Read by title, December 20, 1892.*]

The long-continued drought of the summer of 1892 was unusually severe, the rise of even a couple of inches was eagerly noted in the city reservoirs and frequent warnings were given to use no more water than was absolutely necessary. The frequent low-water mark of the Schuylkill and its well-known impure condition in dry seasons are strong reasons for causing us to seek a new supply of pure and wholesome water. Even if artesian wells will not entirely take the place of the Schuylkill they will at least prove a powerful aid, both in quality and quantity. After keeping a complete record of more than twenty wells that have been drilled recently in Montgomery, Philadelphia, Chester and Delaware Counties I would strongly urge a trial of artesian water. The two main points to consider are the purity and the quantity. First, as regards purity, it is a well-known fact that water which has filtered through from 200 to 500 feet of rocky strata is practically free from organic and all deleterious matter. It is never muddy or dirty but always clear and free from sediment. The wells are cased or lined with iron pipe sometimes to a depth of 100 feet. This effectually shuts off any surface drainage, so that it would be impossible for disease germs which are common in river water to reach these deep wells. As a rule artesian water is pure, sparkling and wholesome. It sometimes happens when a well is newly drilled that the water may have a slight mineral taste, due to the salts of lime, magnesia, potash and iron dissolved by being in contact with the rocks for a long time, or it may be a trifle hard. This, however, from experience, we know, is rarely the case, and it soon disappears when the water has been pumped for a certain

time because new water filters in and takes its place. One instance in particular may be given in this city where the water was used for boilers and became quite soft on continuous pumping. The water of nearly all the wells drilled in this vicinity is in constant use for drinking water and has proved satisfactory.

It will be urged by many, no doubt, that the supply derived from artesian wells is insignificant and, as a rule, that it is difficult to find water-bearing strata in this vicinity. Such, however, is not the case. Nearly all the rocky strata within an area of twenty miles of Philadelphia will yield water whether the rocks be mica schist, syenite sandstone or limestone. Occasionally you may find a locality that is barren, but this is rarely the case.

A comparison of the wells drilled in Europe and in this vicinity may be of interest. The wells drilled abroad have furnished an abundance of water for the supply of cities. At Grenelle, near Paris, a well was drilled to a depth of 1,798 feet, when the water stratum was reached a column of water rose in the well that furnished 36,000 gallons per hour, the entire water supply of a suburb of Paris. The well drilled at Passy has a diameter of 2 feet 4 inches and is 1,900 feet deep. From this a column of water rose to the height of fifty-four feet and furnished 5,582,000 gallons per day. Many artesian wells have been drilled in the chalk strata around London. One well alone, at Chadwell near Ware, yielded London over 4,500,000 gallons per day toward its water supply.

The Kentish Town Water Works have a well nearly 1,000 feet deep. It is said there were two wells drilled at Chicago each five inches in diameter, one 1,000 feet and the other 700 feet deep, which furnished 800,000 gallons daily to the water supply. A well of three-inch bore and 2,000 feet deep was drilled at Louisville, Ky., and furnished nearly as much water as the deep well near Paris.

It may truthfully be urged that the geological formation of Philadelphia and vicinity is different from that of Paris and London, but the records of a few wells drilled in this locality will show that we have prolific water-bearing strata

in Southeastern Pennsylvania. A well was drilled by the Oriental Bath Company, at 1104 Walnut Street, Philadelphia, through sixty-six feet of clay and 200 feet of mica schist and gneiss rock. It yields 6,000 gallons per hour and rises to within twenty-eight feet of the surface. The Pennsylvania Railroad drilled ten shallow wells near Radnor within a space of an acre to supply the water tanks and a pumping station. These wells when connected and tested by continuous pumping yielded 288,000 gallons per day. Deep wells at Radnor do not give much water. At Lansdale, along the North Pennsylvania Railroad, a few miles north of Philadelphia, there is no water supply except that derived from an artesian well. This well was drilled to a depth of 611 feet, and is cased or lined with iron pipe to a depth of 259 feet; with an improved pump, it could give 200 gallons per minute or 288,000 gallons per day. The supply is said to be practically inexhaustible. Lansdale is not a particularly good locality for water except at a great depth, because the clay slate, shale and sandstone are tightly packed and the water soaks slowly between the bed planes. The borough of Jenkintown is supplied with artesian water and is in the same belt of mica schist rock as Philadelphia wells. One well is 324 feet deep, the other is 349 feet deep. They will each yield 9,000 gallons per hour, and not only supply Jenkintown with water, but also the surrounding twenty villages for a distance of three miles. The water is soft. Artesian wells drilled in the mesozoic or new red sandstone at Newark, N. J., have yielded an abundance of water. Three wells of six-inch bore, and each less than 100 feet in depth, flowed at the rate of 250,000 gallons each per day. Another deeper well in the same city is yielding 800,000 gallons per day. This is a favorable locality, because the water-bearing stratum underlies a thick bed of clay. Wells drilled in the same belt of mesozoic sandstone at Norristown, Pa., yield over 3,000 gallons per hour with small pumps. Many other instances of prolific wells, such as those at Atlantic City and Ocean Grove, can be given; but enough has been said to show that we have water-bearing strata. Of course, it would be impossible to supply a city the size of Philadel-

phia wholly with artesian water, but in seasons of long-continued draught, such as the summer of 1892, when the rise of even a couple of inches in the reservoirs was eagerly noted, artesian wells would be an enormous gain. In a deep well, when a water crevice is struck near the bottom in drilling, it can be widened and the supply of water enormously increased by exploding nitro-glycerine in the wells in precisely the same manner that it is employed in the oil regions. Tin canisters containing the proper amount are lowered and exploded by means of electricity. The explosion widens the bottom water crevices.

The city of Philadelphia is underlaid with an immense deposit of clay which artesian borings have shown is fifty feet in thickness, and in many parts of the city much deeper. Clay is impervious to water, and this great clay bed checks to a great extent, although not wholly, the filtration of surface drainage. It must not be thought for an instant that the clay is a perfect barrier and wholly prevents the surface water from getting to the mica schist rocks beneath, because instances can be given of surface water getting below and showing on analysis. One fact then cannot be too strongly emphasized, artesian wells must be thoroughly cased with iron pipe from the surface, the deeper the better. When they are properly cased for 100 feet or more there is little if any danger from surface contamination. When the well is finished it should be pumped for a couple of hours, and the next day a sample taken for chemical analysis. If any trace of surface contamination is shown, the casing should be driven deeper until analysis proves the water to be perfectly pure. These precautions are only necessary in large cities and towns. Artesian wells drilled in the country will always yield pure water. A series of artesian wells drilled in Fairmount Park, some distance out, would yield an abundance of pure and wholesome water, which would be free from surface contamination of any kind.

A series drilled near the new reservoir at Roxborough would give the purest water. When artesian wells are drilled in solid rock in the country, it is not necessary always to line them with iron pipe, as a hard compact rock will remain open from top to bottom when once drilled.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, November 22, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 22, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-seven members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing, which were approved and ordered paid.

Two nominations to membership were referred to the Committee on Admissions. The Committee reported two members elected since last meeting.

Nominations for officers for 1893 being in order, Prof. E. J. Houston was nominated for President for another term, but declined with regret on account of the press of other business. The following nominations were then made and duly seconded:

For *President*, ...	Mr. Elmer G. Willyoung.
For *Vice-Presidents*, ...	Prof. Edwin J. Houston, Mr. C. W. Pike.
For *Secretary and Treasurer*, ...	Prof. L. F. Rondinella.
For *Conservator*, ...	Dr. Wm. H. Wahl.

(*The election will take place at the December meeting.*)

Mr. E. G. Willyoung read a paper on "Some New Apparatus for the most exact Comparison and Adjustment of Resistance Standards and the Determination of Temperature Coëfficients." The paper was illustrated with some fine examples of the apparatus described, and was referred for publication.

Mr. O. T. Louis presented a communication on "Errors in the Determination of Areas from Measured Diameters." This was illustrated by a diagram and blackboard sketches, and was referred for publication.

Mr. Nelson H. Genung read a paper on "Recent Improvements in the d'Arsonval Galvanometer," illustrated by a fine instrument of the type made by Queen & Co., arranged in working order. Referred for publication.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

RECENT IMPROVEMENTS IN D'ARSONVAL GALVANOMETERS.

By Nelson H. Genung.

[*Read at the stated meeting of the Electrical Section, November 22, 1892.*]

To see an elaborate electrical instrument highly lacquered and polished standing in the show-case of some college laboratory is one thing; to see the same or a similar instrument in the working drawings or in a thousand and one pieces on the workman's bench ready for assembling is quite another thing. It is in the latter case only, when one sees here and there a part insignificant in itself but on which may depend the success of the instrument as a whole, that one is brought to realize the necessity of looking after the smallest details in instrument construction. It is certainly difficult for a person unacquainted with the manufacture of fine instruments to fully appreciate the range of electrical and mechanical knowledge which one must possess in order that he may plan the working drawings for a high-grade instrument which shall work satisfactorily when completed, which shall conform strictly to mathematical principles, which shall include in neat and attractive mechanical form all the latest improvements applicable to that particular type of instrument, and which shall, in so far as is possible, conform to standard sizes of material so as to reduce the cost of manufacture to a minimum. It is only by continuous study and practice that one acquires satisfactorily the knowledge necessary for such an undertaking.

A thorough and systematic study of the Deprez-d'Arsonval type of galvanometer has recently been made by the writer with the ultimate intention of throwing this class of instruments into a variety of forms for both the college and commercial trades. The paper presented to you this evening will include, among other things, an historical sketch of the Deprez-d'Arsonval galvanometer, a little mathematical reasoning concerning aperiodic galvanometers of this type,

a brief review of the most noteworthy improvements recently made in this class of instruments, and a detailed description of a d'Arsonval galvanometer, which, in the course of its design, has been thoroughly criticised from both a theoretical and mechanical standpoint, and which, although not yet fully completed, has yielded extremely satisfactory results.

A galvanometer is an elctrical measuring instrument in which use is made of the electro-magnetic properties of currents. A coil of wire traversed by an electric current sets up a magnetic field of its own, the strength of which at any point depends on the strength of the current flowing. Suppose this coil to be mounted vertically, and with its plane parallel to the magnetic meridian, a magnetic needle suspended in its axis will, when no current is flowing, assume a direction parallel to the horizontal component of the earth's field, but on introducing a current the needle will be deflected from this its zero position, through some definite angle depending on the relative strengths of the two magnetic fields involved. Thus we see that by this method the measurement of current is reduced to a measurement of the strength of field produced by it.

Numerous modifications may be introduced so that for a given strength of current the angular deflection of the needle may be materially increased. This increase in the sensibility, as it is called, has been brought about in several ways, such as decreasing the torsional control of the suspension fibre, reducing the moment of inertia of the movable parts, increasing the length of wire acting on the needle, reducing the mean distance of the coil from the needle and decreasing the strength of the earth's field in the vicinity of the needle by means of a control magnet. A discussion of these points being beyond the range of this paper will be omitted. Brief reference, however, will be made to the last one mentioned as it furnishes a stepping-stone to what is to follow concerning d'Arsonval galvanometers.

The extreme annoyance experienced in attempting to use a galvanometer of the above-described type, made sensitive by neutralizing the earth's effect on the needle by means of a control magnet is well-known. The original or earth's field

and the temporary field set up by the control magnet being nearly equal and opposite in direction destroy, almost completely, each other's effect on the needle. A slight variation in strength or direction of either of these fields or the introduction of a third field, however weak it may be, is often sufficient to cause the needle to turn completely around. This subject received full and thorough treatment in a paper read by Mr. Elmer G. Willyoung,* at our last meeting.

It was mainly with the idea of obviating this difficulty that Marcel Deprez,† about the year 1880, introduced into galvanometer construction what has since proved an important and desirable modification. He placed the galvanometer needle between the poles of a powerful horse-

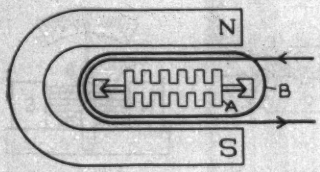

FIG. 1.

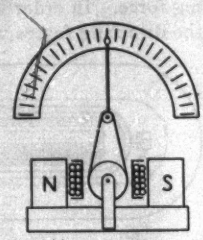

FIG. 2.

shoe magnet, thus freeing it from all local magnetic disturbances and giving it a short period of oscillation, but at the same time causing it to lose almost entirely its sensibility. He afterwards substituted a soft iron laminated needle which when placed in position became strongly polarized by induction. *Fig. 1* shows the general arrangement adopted by him, and known under the name "*galvanomètre à arête de poisson*," galvanometer of herring-bone work. The soft iron needle *A* is mounted within the galvanometer coil *B*, and both are surrounded by the horseshoe magnet *N S*.

* "A New Standard Ballistic Galvanometer with Variable Sensibility and without 'Drift,'" by Mr. Elmer G. Willyoung, New York *Electrical Engineer*, November 16, 1892.

† "On Electrical Measuring Instruments: Ammeters and Voltmeters," by Marcel Deprez, *La Lumière Électrique*, April 30, and November 5, 1881.

The range of movement of the needle is, however, very small and the deflections far from being proportional to the currents measured.

A multiplying device, similar to that shown in *Fig. 2*, was added a little later, which obviated these difficulties to a considerable extent. The scale was at that time usually divided into degrees, thus necessitating the use of a table of values or a calibration curve.

The next step was to retain this powerful control magnet and astaticise the movable system. M. d'Arsonval* concluded that so long as the moving parts contained any magnetic material this would be utterly impossible, the directing force being always very great as compared with the deflecting force. In order to accomplish this he aimed at making the directing forces very weak and the deflecting force very

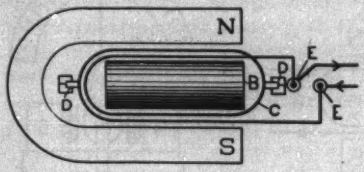

FIG. 3.

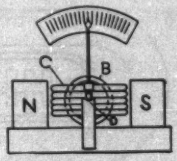

FIG. 4.

powerful, and succeeded by fixing the soft iron needle and making movable the current coil of the Deprez instrument. The general arrangement remaining the same, the number of parts was not materially increased. The control being non-magnetic could be made as weak as might be desired, the deflecting force remaining practically the same. *Figs. 3* and *4* show d'Arsonval's arrangement in which *N S* represents the permanent horseshoe magnet, the poles of which are thirty millimetres apart; *B*, the fixed soft iron tube or needle, about twenty-five millimetres outside diameter, which extends nearly the whole length of the magnet; *C*, the coil mounted on knife-edges *D D* and provided with mercury contacts *E E*, coinciding with the axis of rotation.

* "A new Deprez-d'Arsonval Astatic Galvanometer," by M. Deprez, *La Lumière Électrique*, September 7, 1881.

Almost any desired sensibility may be attained by properly adjusting the centre of gravity of the movable system.

A few years later this galvanometer was constructed as shown in *Fig. 5*, by M. Carpentier, in which form it has practically remained to the present day.

Lord Kelvin probably first made use of the above principle in the construction of his siphon recorder used as a receiving instrument in submarine telegraphy. M. d'Arsonval* says regarding his own application of this principle: "This apparatus rests upon the same principle as does the siphon recorder of Wm. Thomson. It is seen that I have

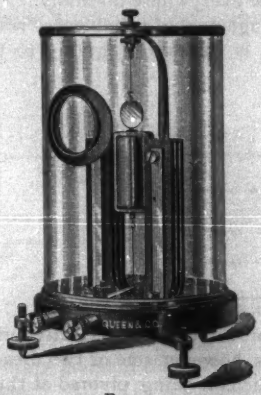

FIG. 5.

arrived at the same combination, starting from another point of view and that I have also transformed into a *galvanometer*, an apparatus which up to then had been used only as a telegraph receiver." In the same article he continues, "I have given to this apparatus the name of *Deprez-d'Arsonval galvanometer* in order to recall its origin."

A successful attempt was made in 1884 by Deprez† to

* "Aperiodic Galvanometers of Great Sensibility," by M. d'Arsonval, extract *de la Revue Internationale de l'Électricité et de ses Applications*, April, 1886.

† "On a Galvanometer in which the Indications are Proportional to the Current Strength," by M. Deprez, *La Lumière Électrique*, December 13, 1884.

construct a d'Arsonval galvanometer giving proportional indications. In an article published by him at about that time he says, "The deflections of the needle are exactly proportional to the intensities of the current even when deflected 120°." Two soft iron pole pieces circularly cut out were employed. These pole pieces *B B*, see *Fig. 6*, and the soft iron cylindrical core *C* were rigidly attached to the magnet. Within the annular space occupied by the coil *A*, the magnetic field is strong and uniform and the lines of force are normal to the polar and core surfaces. The coil thus always moves through a uniform magnetic field, cutting the lines of force everywhere normally.

Another arrangement of pole pieces,* see *Fig. 7*, has been proposed which is capable of giving to the coil a much

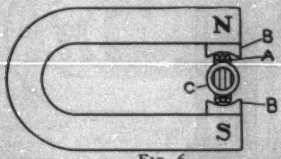

FIG. 6.

FIG. 7.

wider range of movement in a perfectly uniform field. This arrangement has, however, one or two disadvantages worth mentioning. The coil being pivoted at the centre *A*, has a comparatively large moment of inertia, which prevents it from coming to rest so quickly as it otherwise would. The amount of "dead" wire is also very great. By "dead" wire is meant all that portion of the coil not so disposed with reference to the field as to assist properly in the deflection, the "active" wire being that portion which moves properly in the magnetic field. This point is very satisfactorily illustrated in *Fig. 8*. The portions *L N* and *M R* in all three of the coils are so disposed, with reference to the axis of rotation and to the lines of force, as to assist in the deflection.

* See *La Lumière Électrique*, March 24, 1888.

The wire making up these portions is called the "active" wire of the coils. The wire making up the portions *L M* and *N R* takes no active part in the deflection, and is, in consequence, called the "dead" wire.

In an instrument to be used merely as a current detector, the deflections being usually very small, it is desirable to concentrate the field as much as possible by employing convex or conical pole pieces, so as to give to the coil a maximum deflecting force. Square or concave pole pieces give a weaker field for the coil at the start, but as the deflections increase the active portions of the coil pass into a gradually increasing strength of field, which makes up for

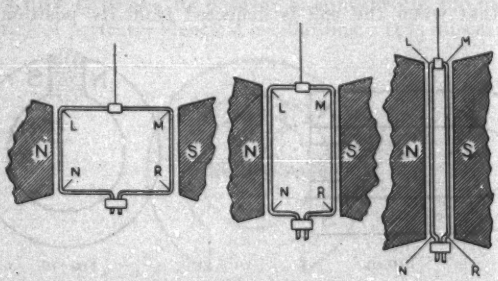

FIG. 8.

the loss in deflecting moment due to the shortening of the arm of the couple.

The leakage of the lines of force around the space occupied by the coil is likely to be much greater in horseshoe than in circular magnets, see *Figs. 9* and *10*. By adopting an arrangement similar to that shown in *Fig. 3*, nearly all the lines are utilized, but the great length necessarily given to the coil in order to capture the comparatively small number of lines near the bend in the magnet, is not a desirable feature in instrument construction. The iron core, however, doubtless tends to distribute the lines somewhat uniformly throughout its entire length. The increase in sensibility by this means is more than counter-balanced by the additional moment of inertia necessarily given to the

coil, which shows that the lines might better be concentrated at or near the poles proper, circular magnets being employed to avoid any appreciable loss due to leakage.

A novel arrangement of coil and magnets has recently been adopted by M. Gaiffe,* of Paris, in milliampèremeter construction. He has done away with the soft iron core and makes the deflections proportional to the intensities by employing two magnets of cylindrical form, as shown in *Fig. 11.* The coil in this arrangement contains a large amount of "dead" wire, being necessarily quite broad, and has a considerable moment of inertia as well. The range of movement, also, is not materially increased.

Turning our attention now to the movable system we find that when the coil is deflected from its position of

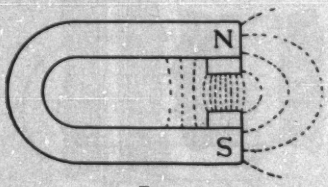

FIG. 9.

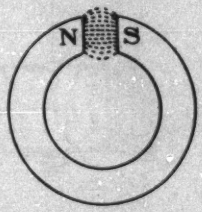

FIG. 10.

equilibrium there is a torsional couple due to the suspension which tends to bring it back. This is the only directive force brought to bear on the system. The moment of this couple is a function of the angle of deflection, and may be made almost anything desired by varying the length and cross-section of the suspension wire. Aside from this directive force, there are various retardative forces at work when the coil is in motion, due to the reaction of induced currents, friction with the air, and the like, which tend to bring the system to rest. These forces are functions of the angular velocity of the system.

In the movement of the coil of a galvanometer of this type we have an example of the rotation of a solid about an

* *La Lumière Électrique*, September 3, 1892.

axis in which case the product of the angular acceleration by the moment of inertia of the movable system is equal to the sums of the moments due to the directive and retardative forces. The differential equation for the movement of the coil thus becomes

$$\Sigma m r^2 \frac{d^2\theta}{dt^2} + A \frac{d\theta}{dt} + B\theta = 0$$

in which θ represents the angular deflection in time t, $\Sigma m r^2$ the moment of inertia of the coil, A a constant for the retardative forces and B a constant for the torsional couple.

Imagine now the retardative forces to become negligable, the coil, when set in motion, acquires the same velocity every time it passes its position of equilibrium and makes a series of perfectly identical oscillations. It is thus said to

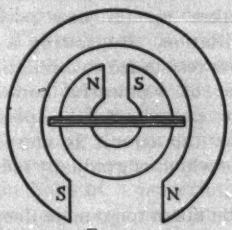

FIG. 11.

have a *periodic* movement. The time of oscillation of the coil may be greatly increased, either by increasing its moment of inertia or by decreasing the directive moment due to the suspensions, the oscillations still remaining isochronous.

If, now, B is left constant and A made to increase gradually, the period becomes greater and greater as the logarithmic decrement increases. Finally, A having attained a considerable value, due to self-induction in this case, the coil on being drawn to one side and released, returns to its position of equilibrium, moving rapidly at first then more and more slowly, finally coming to rest. Infinite time is required theoretically for accomplishing this; practically, however, the zero point is reached in the course of a few seconds.

Suppose the only damping effect on the needle to be that due to induction; A is then equal to

$$\frac{F^2 S^2 n^2}{R}$$

where F represents the strength of the field; S, the area of the coil; n, the number of turns composing it, and R, the total resistance in circuit. Since the value of A depends on the total resistance R as the only variable, the field remaining constant, it should become zero when R reaches infinity; that is, when the coil is on open circuit. As a matter of fact, however, A does not become zero quite since the damping, due to friction with air, is not wholly negligable. By decreasing R the value of A increases and the coil finally assumes an *aperiodic* movement. A solid rotating about an axis is said to have an "aperiodic" movement when it takes up its new position immediately and without oscillation. By setting a d'Arsonval galvanometer coil of low resistance to oscillating on open circuit between the poles of a powerful horseshoe magnet, the transition from the periodic to the aperiodic movement is easily followed, as the circuit is closed through a high external resistance which is gradually reduced until the coil is short-circuited.

Time will not be taken to go more deeply into the theory of this instrument, as there are many points of more interest and greater importance which should be taken up. The theory of aperiodic galvanometers of the Deprez-d'Arsonval type has been thoroughly reviewed and experimentally verified by M. Ledeboer,* to whose paper the reader is referred in case he desires to go more deeply into the theoretical reasoning.

As early as 1881, Deprez† speaks of short-circuiting the coil for the purpose of damping the oscillations. The only resistance in circuit then being that due to the coil, the

* "Theory of Aperiodic Galvanometers," by M. Ledeboer, *Journal de Physique*, second series, vol. vi, p. 53, 1886. Also *La Lumière Électrique*, June 26, 1886.

† "New Deprez-d'Arsonval Astatic Galvanometer," by M. Deprez, *La Lumière Électrique*, September 7, 1881.

currents induced are sufficient to bring the needle slowly to rest. Closing the article, Deprez says: "This characteristic makes the instrument applicable to the measurement of resistances."

In the well-known Weston instrument, constructed on the Deprez-d'Arsonval plan, the coil is wound on a copper frame which serves the purpose of damping very effectively. This frame acts the same as would a single turn of heavy wire dead short-circuited on itself, and moving as it does in a powerful magnetic field the inductive effect is sufficient to make the instrument practically "dead beat."

Weston has also proposed the electrolytic deposition of a layer of copper over the entire surface of the coil, which shall serve the same purpose. Ayrton and Mather* have encased the coil of their recently constructed d'Arsonval in a silver tube, which serves both as a damper and as a protection to the coil. The coil is rigidly attached to this tube, which forms a part of the movable system.

Numerous other modifications of this method for damping have been proposed, such as short-circuiting any number of turns on the coil, adding a separate coil which shall be short-circuited, providing a copper disc which shall rotate properly between the poles of a powerful magnet, and the like, all of which are amply sufficient for the purpose.

Apparently no particular attention was paid to the best form of coil to be used in d'Arsonval galvanometers at the time when the best shape of pole pieces was being so thoroughly studied. In a paper on galvanometers, by Messrs. Ayrton, Mather and Sumpner,† the conclusion is drawn that the most sensitive galvanometer attainable is one of the d'Arsonval type suitably modified. For accomplishing this they say that the pole pieces should be very close together, the coil very small and no stationary iron core employed. The sensitiveness could be further increased by employing electro-magnets instead of permanent ones.

* "The Ayrton-Mather-d'Arsonval Galvanometer," *London Electrician*, July 29, 1892.

† "On Galvanometers," a paper read before the Physical Society, *London Electrician*, February 7, 1890.

The coil should also be long and narrow and the controlling force reduced to a minimum whenever great sensibility is desired.

Mr. Mather,* a little later, presented a paper before the Physical Society, in which he exhibited the results of a thorough study on the best section of coil perpendicular to the axis of rotation. Quoting from this article: "Since for a constant period the controlling moment at unit angle must be proportional to the moment of inertia, the problem is to determine the shape of the section so that the ratio of the deflecting moment to the moment of inertia may be a maximum." The six sections shown in *Fig. 12* are taken from the above-quoted article. In *A* the deflecting moment per unit moment of inertia is 1·02, in *B* it is ·80, in *C* ·97, in

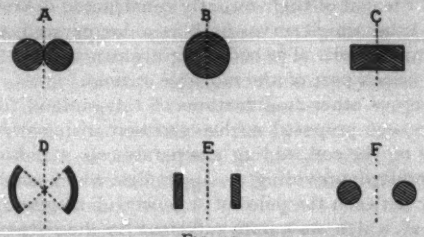

FIG. 12.

D ·44, in *E* ·47 and in *F* ·40. Coil *A* is, as may be seen, more efficient than any of the others. These calculations are based on coils in which the length is great in proportion to the cross section.

As to the kind of wire to be used in these coils nothing in particular need be said. Copper is usually employed the same as in most galvanometers of the various other types. If, however, the accuracy of the instrument depends to any considerable extent on the permanency of its resistance, it is better to employ a wire, having a much lower temperature coëfficient although its resistance may be considerably increased.

As has already been pointed out, the coil of the d'Arsonval

* London *Electrician*, April 11, 1890.

galvanometer in its earliest form rested on knife-edge supports, and was provided with mercury cup connections and gravity control. In the Carpentier arrangement the coil was mounted on a vertical axis. The suspensions in this latter case being of wire served the threefold purpose of suspension, conductor and control. A little later, long spiral springs were employed as conductors and control the coil being supported by means of a cocoon fibre.*

Suspension wires in a variety of sizes, shapes and materials have been employed at various times. Silver, platinum, silver-platinum, platinoid, German silver and phosphor-bronze are all materials for this purpose, the phosphor-bronze being on the whole the best, as it is little likely to corrode and is the least likely to take a permanent "set," thereby causing a slight change in the "zero point." The variation in sensibility due to the "time change," is also very small in the case of phosphor-bronze suspensions.

Flat strips possess a much smaller control than do round specimens of the same material having the same area of cross section. A suspension having a rectangular cross section the breadth of which is five to ten times the thickness has been recommended as the best form to adopt whenever a minimum control is desired. All other conditions remaining the same, Prof. Ayrton concludes that a flat strip suspension will give a deflection five times as great as will a round suspension of the same cross section. The liability to error due to a shifting of the "zero point," the result of a slight permanent "set," is much reduced by employing the strip. The radiation surface is at the same time considerably increased, this being often a matter of great importance in cases where very fine suspensions are necessary.

For commercial work the coil is usually supported in jewel bearings, springs serving for both control and conductors. In the well-known Weston instrument and in the milli-ampèremeters recently placed on the market by Mr. Gaiffe, flat spiral springs made from phosphor-bronze strip have been adopted.

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* *La Lumière Électrique*, 1887, p. 530.

In Prof. Ayrton's article, to which reference has previously been made, is described a form of d'Arsonval galvanometer having a coil of platinoid wire, the cross section of which is the same as that shown in *A*, *Fig. 12*, the iron core being necessarily absent. In this form the coil, mountings and frame work supporting the same are bodily removable from the instrument. A d'Arsonval galvanometer, designed by Messrs. Ayrton and Mather, was exhibited for the first time at a recent meeting of the Physical Society. This instrument, as you can readily see from the one before you, employs the narrow coil mounted in a silver tube, which forms a part of the movable system, and is suspended by a flattened phosphor-bronze wire. A button presses against the side of the silver tube by means of a spring which preserves the system from injury, when transportation is desired. The magnet is of one piece of metal, and has square pole faces. The movable system is mounted in a brass tube which may be removed, and another tube containing another coil slipped in place. The mirror cage and clamping device are both attached to this tube. The total height of the instrument is 6 inches, length of suspension tube $5\frac{3}{4}$ inches, outside diameter of magnet 4 inches, length of coil 2 inches, and diameter of silver tube $\frac{1}{4}$ inch. The coil has a period of about one and one-fourth seconds and is damped by the silver tube sufficiently to bring it to rest with about five complete oscillations.

We will now turn our attention to the new Queen-d'Arsonval galvanometer, this being its first appearance outside of their factory and electrical laboratory. *Fig. 13* shows the assembled instrument. All the parts are of rigid construction, and the instrument, as a whole, while it presents a pleasing appearance, presents a rugged workshop-like appearance as well.

The magnet has an outside diameter of four and one-half inches, and is built up of thirty-five discs one-tenth of an inch thick held together by means of three bolts. These discs are cut from the best sheet steel obtainable and are hardened glass hard. After having been thoroughly magnetized great care is exercised not to subject them

to any rough usage. The magnet rests on a sheet of hard rubber *A*, *Fig. 14*, which insulates it completely from the metal tripod base. The pole faces *BB* are concaved, thus tending towards uniform deflections. At the same time the corners are slightly rounded, thus avoiding too great a leakage around the coil. The suspension tube *C*,

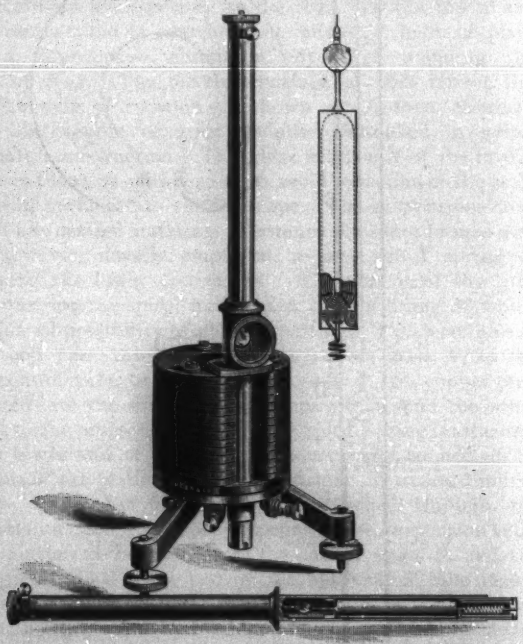

FIG. 13.

sixteen inches long over all, slides freely between the poles, which, together with the mirror cage *D* attached to them, hold it rigidly in position. This tube containing the entire system may be slipped out without the necessity of loosening a single screw and another tube put in place. Connections are made automatically by means of sliding contacts

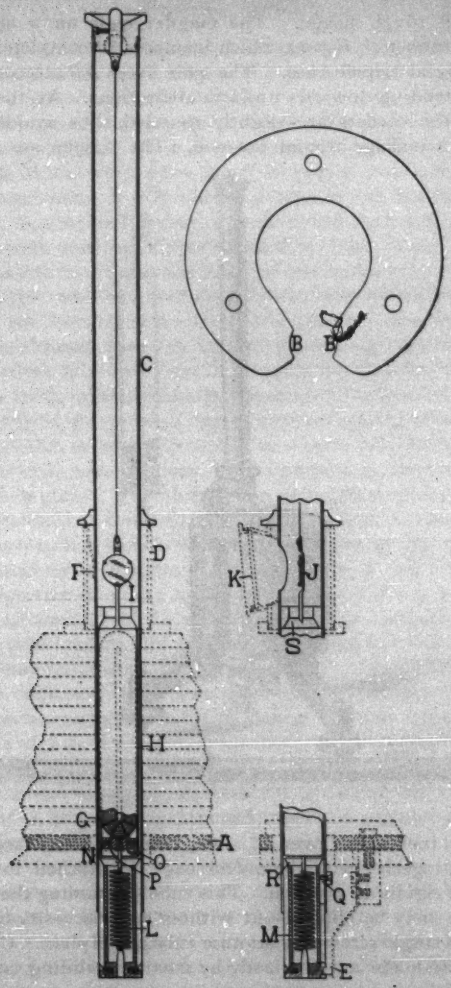

FIG. 14.

at *E* and *F*. The coil *G* fills the aluminum tube *H*, to which it is rigidly attached. The space within this tube allotted to the coil is 3½ inches long by $\frac{9}{16}$ inch in diameter. The coil itself has a cross section represented by two tangential circles, as shown in *Fig. 8*, this being the most approved shape. It may be wound either of copper, or of platinoid wire as may be desired. To the top of the aluminum tube is attached the mirror *I*, held in place by a three-armed aluminum clip, thus avoiding the use of wax. The silvered surface of this mirror lies in the axis of rotation as shown at *J*, thus eliminating one source of error usually overlooked in galvanometer construction. The glass window *K* of the mirror cage is tilted, as shown, so as to avoid reflection of the scale from its surface into the telescope. The suspensions may be of any desired material. Flattened phosphor-bronze wire is, however, usually employed, a long spiral spring *L*, forming the lower connection. The portion of the tube surrounding the spiral has a hard rubber lining *M*, which avoids all possibility of short-circuiting. The terminals of the coil pass through the hard rubber base *N*, of the aluminum tube, one being soldered at *O*, to a copper plug riveted into the side of the aluminum tube, and the other at *P*, to the projection to which the spiral spring is attached. The lower end of this spiral is electrically connected, by means of the platinized spring contact *E*, to one binding post. The other binding post is reached through the aluminum tube, the upper suspension, the suspension tube, the platinized contact at *F*, the mirror cage *D*, and the magnets. The lower end of the suspension tube makes sliding contact with the tube proper, its range of movement being limited by the slot and pin at *Q*. As a means for clamping the system, the upper edge of this sliding portion is reamed out, as shown in the figure at *R*, and just above the aluminum tube is fastened a collar *S*, similarly shaped. When the lower end of the tube is shoved up, the coil is not only clamped but lifted slightly as well, thus entirely relieving the suspension wire of all strain. By this means the coil is held perfectly rigid during transporta-

tion without the least fear of injury to any part of the system.

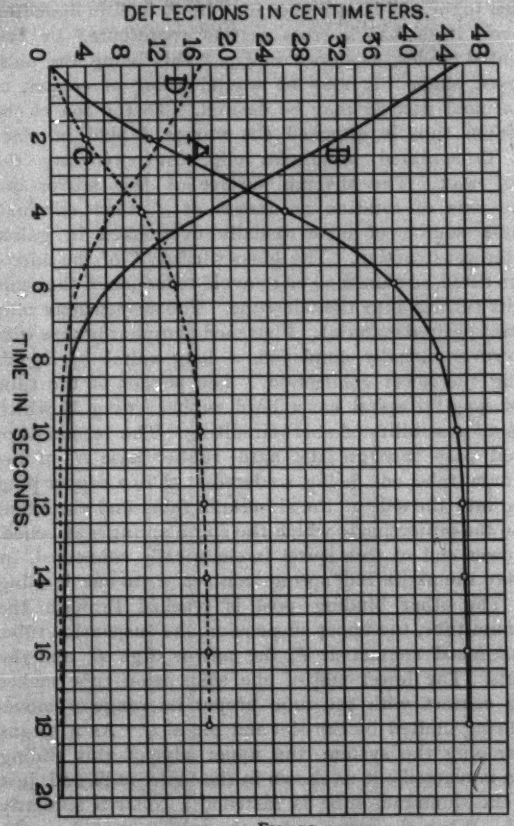

FIG. 15.

Starting the coil of this instrument from a position of rest, its position was noted every two seconds until it had again come completely to rest. The curves, *Fig. 15*, are

intended to represent this movement. Curve *A* was obtained by closing the circuit through a resistance sufficient to give about forty-six centimetres deflection. Curve *B* was obtained

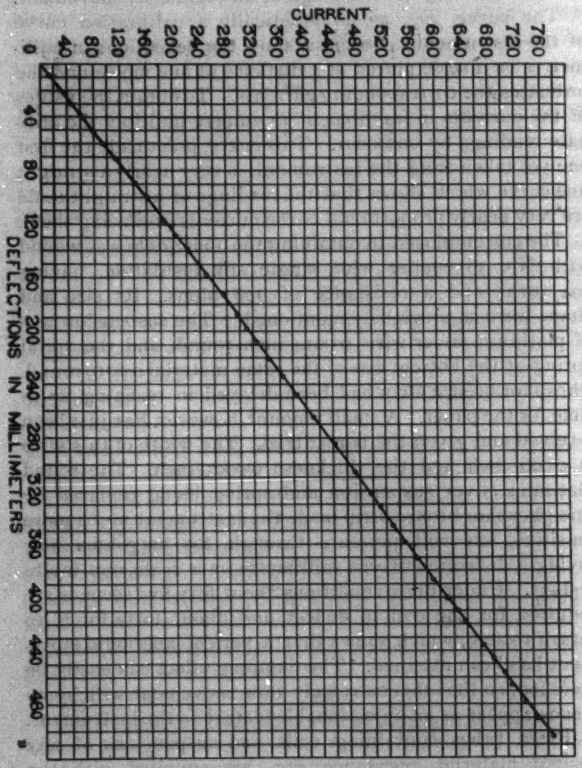

FIG. 16.

by breaking the circuit thus allowing the needle to return to zero. Curves *C* and *D* were obtained in a similar manner, the deflection being only about sixteen centimetres. From

these curves it is easily seen that the movement of the coil is absolutely aperiodic; that is, it moves directly to its position of rest, approaching it more and more slowly, without showing the least sign of an oscillatory movement.

The curve, *Fig. 16*, is practically a calibration curve of the instrument. Abscissæ show the deflections in millimetres on a scale placed at a distance of one metre and the ordinates the corresponding currents. To obtain the values of the currents in fractions of an ampère multiply the ordinate readings by ·00000001. This curve, practically the first one yet taken from the instrument, is very nearly a straight line curve which shows that the readings on a straight scale are very nearly proportional to the currents producing them.

The coil employed in obtaining the above data was wound with No. 36 copper wire, single silk insulation, having 694 turns and a resistance of 178 ohms. Its size and shape were as previously mentioned. The suspension was of platinum silver wire, 0·0014 inch round, and the spiral spring at the bottom was of the same material 0·0019 round. Phosphor-bronze strip has been delayed in reaching us in time for the paper. A small amount, however, has just been received and given the barest trial. The width of this strip is 0·006 inch and the thickness 0·0005 inch. The round platinum silver suspension and spring being replaced by this phosphor-bronze strip made the instrument much more sensitive, one volt pressure through 200 megohms now giving a deflection of one millimetre on a scale one metre distant. Under these conditions about fifty-five seconds are required for the coil to deflect and about forty for it to return to zero, which shows that a perfect aperiodic movement has been attained. The damping effect can easily be modified, so that this extremely slow movement will by no means appear as an objectionable feature to the instrument.

Extra tubes containing coils and suspensions of any desired material, resistance, etc., are supplied with the instrument. Tubes containing coils intended for ballistic purposes are also supplied. These latter are free from damping due to induction, a short-circuit key being amply sufficient to stop all movement of the system whenever desired

The work on d'Arsonval galvanometers is being continued with the intention of getting out an instrument of this type which shall have an extremely high sensibility, rivalling that of the Thomson square pattern galvanometer. The results thus far are very encouraging, and within a few months you may hope to see this instrument in tangible form.

ERRORS IN THE DETERMINATION OF AREAS FROM MEASURED DIAMETERS.

By O. T. Louis.

[*Read at the meeting of the Electrical Section, held November 22, 1892.*]

In scientific determinations made at the present day, the accuracy of the determination is the paramount question. The problem is not to measure a length to ·01 millimetre or a resistance to ·0001 of an ohm, but to determine a length or a resistance with an accuracy of ·01 or ·001 of one per cent. Little improvements often increase accuracy to a marked extent. To one of these little wrinkles, I would call attention to-night.

In some recent work in the measurement of conductivity at Queen's Laboratory at Ardmore, I had occasion to study the methods of determining the cross section of the specimens in question. The area could be determined in two ways: by calculation from the volume obtained by the determination of the mass and specific gravity and by calculation from a directly measured diameter. The latter method is of course the simpler and where a good chemical balance is absent the only one to be employed. To call attention to a few points to be observed in this latter method is the object of this paper.

Let δ equal the true diameter of any geometrical cross section, the area of which is to be determined.

Then $k\,\delta^2$ can be taken as the area of that cross section, k being a constant varying from

$$1 \text{ to } \frac{\pi}{4}$$

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Then $k\,\delta^2$ can be taken as the area of that cross section, k being a constant varying from

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for all figures from the square to the circle.

In measuring a diameter by micrometer calipers two things may occur: the diameter may be measured too large by slightly twisting the calipers or by the presence of bends, or made too small by crushing the surfaces measured. Let the error thus made be called a. Then the measured diameter is

$$(\delta \pm a) \tag{1}$$

and the area becomes

$$k\,(\delta \pm a)^2 \tag{2}$$

the true area being

$$k\,\delta^2 \tag{3}$$

and, therefore, the error is

$$k\,\delta^2 - k\,(\delta \pm a)^2 \tag{4}$$

and the percentage of error is

$$\frac{k\,\delta^2 - k\,(\delta \pm a)^2}{k\,\delta^2} \tag{5}$$

Simplifying expression (5) we obtain

$$\frac{\delta^2 - (\delta \pm a)^2}{\delta^2}$$

$$\therefore \frac{\delta^2 - \delta^2 - 2\,a\,\delta - a^2}{\delta^2}$$

and

$$\frac{\delta^2 - \delta^2 + 2\,a\,\delta - a^2}{\delta^2} \tag{6}$$

or

$$\frac{2\,a\,\delta + a^2}{\delta^2} \tag{7}$$

$$\frac{2\,a\,\delta - a^2}{\delta^2} \tag{8}$$

From expression (7) will be seen that when the diameter is measured too large, then the percentage of error in measuring the area is

$$\frac{2\,a\,\delta + a^2}{\delta^2} \tag{7}$$

and the percentage of error when the diameter is measured too small

$$\frac{2\,a\,\delta - a^2}{\delta^2} \tag{8}$$

A comparison and discussion of expressions (7) and (8) bring out several interesting points.

The percentage of error in measuring the diameter is

$$\frac{a}{\delta}$$

in measuring the area the maximum error is

$$\frac{2\,a\,\delta + a^2}{\delta^2}$$

the ratio of the two errors is, therefore,

$$\frac{2\,a\,\delta + a^2}{\delta^2} \times \frac{\delta}{a} = \frac{2\,\delta + a}{\delta} \tag{10}$$

Expression (10) may be given the form

$$2 + \frac{a}{\delta} \tag{11}$$

Expression (11) shows us two interesting facts. First, when the diameter is measured greater than it really is then the minimum ratio of the error of area to diameter is 2, and the maximum ratio is 3. a is generally small compared with δ. This brings out the fact that the common opinion that the error in the area is equal to the square of the error in the diameter is erroneous Expression (11) shows that the actual error is never far from double the error of the diameter.

Hitherto we have been considering the case when the measured diameter is greater than the actual. Let us consider expression (8) in which the measured diameter (due say to crushing) is less than the actual diameter. In this case we have the percentage of error as

$$\frac{2\,a\,\delta - a^2}{\delta^2}$$

If we divide this by

$$\frac{a}{\delta}$$

we obtain as before the ratio of the error of area to the error of the diameter.

$$\frac{2\,a\,\delta - a^2}{\delta^2} \times \frac{\delta}{a} = \frac{2\,\delta - a}{\delta} = 2 - \frac{a}{\delta} \qquad (12)$$

From expression (12) we see, as before, that the ratio is not far from 2, but is always less than 2.

A comparison of expressions (7) and (8) will bring out an interesting fact. From (7) we have

$$\frac{2\,a\,\delta + a^2}{\delta^2}$$

from (8) we have

$$\frac{2\,a\,\delta - a^2}{\delta^2}$$

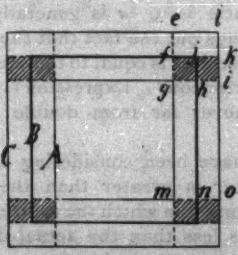
the difference is therefore

$$\frac{2\,a^2}{d^2} \qquad (13)$$

In other words, admitting the same error, we gain

$$\frac{2\,a^2}{d^2}$$

by crushing the wire by an amount a, to having the calipers too loose by the same amount a.



The same thing can be shown more clearly graphically. Let us take the special case of a square, as that permits of simpler demonstration. Three squares are shown, *A B*

C; B is the correct area we desire to measure; C is the measured area when the calipers are too loose; A when the calipers crush the surface to be measured. The diameter of C is $B + a$. Of A is $B - a$. The errors in measuring the areas are the bands between A and B and between B and C. An inspection of the diagram shows that the band $g\ h\ m\ n$ is balanced by the band $h\ n\ o\ i$; the corner $f\ j\ h\ g$ by $j\ k\ h\ i$; but the part $e\ l\ f\ k$ is unbalanced. Similarly for each corner we have a part equal to $e\ l\ f\ k$; therefore, the total area between B and C exceeds the total area between A and B by $4\ e\ l\ f\ k$. But $e\ f\ l\ k$ has the dimensions $\frac{1}{2}\ a \times a$ therefore

$$4\ e\ l\ f\ k = 4\ (\tfrac{1}{2}\ a \times a) = 2\ a^2$$

or the error in measuring the area as C is $2\ a^2$ greater than in measuring it as A; the error percentage gained being

$$\frac{2\ a^2}{d^2}$$

as shown above. Summing up the foregoing it follows that it is always an advantage to screw up the calipers quite tightly as even if the surface is slightly crushed something

$$\left(\frac{2\ a^2}{d^2}\right)$$

is gained over having the calipers too loose by the same amount a. This rule I have found especially advantageous to use when measuring the conductivity or specific resistance of wire. The surfaces to be measured are in this case generally of sufficiently hard material to prevent any serious crushing by screwing up the calipers tightly. On the other hand, there is a strong probability that if this is not done the kinks and bends which will exist, no matter how carefully the wire be straightened, will increase the apparent diameter. The usual precautions should of course be observed; *e. g.*, the determination of the mean diameter by reading along the whole length of the specimen under examination, test of the zero, etc. By observing these precautions the probable error can be reduced so as not to exceed the errors made in the measurement of the resistance.

ARDMORE, Pa, November 22, 1892.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, Dec. 21, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 21, 1892.

MR. JOS. M. WILSON, President, in the chair.

Present, 195 members and twelve visitors.

Additions to membership since last report, twenty-seven.

The following nominations were made:

For *President*	(to serve one year), . . .	JOSEPH M. WILSON.
" *Vice-President*	(" three years), . . .	CHARLES BULLOCK.
" *Secretary*	(" one year), . . .	WM. H. WAHL.
" *Treasurer*	(" " "), . . .	SAMUEL SARTAIN.
" *Auditor*	(" three years), . . .	SAMUEL H. NEEDLES.
" "	(in place of Wm. A. Cheyney, deceased), .	FRANCIS LECLERE.

For the *Board of Managers** (to serve three years).

CHARLES H. BANES,	ISAAC NORRIS,	COLEMAN SELLERS,
F. LYNWOOD GARRISON,	THEODORE D. RAND,	S. LLOYD WIEGAND,
WASHINGTON JONES,	STACY REEVES,	*J. Howard Gibson.*

For the *Committee on Science and the Arts** (to serve three years).

ARTHUR BEARDSLEY,	G. M. ELDRIDGE,	E. F. MOODY,
HUGO BILGRAM,	F. L. GARRISON,	E. ALEXANDER SCOTT,
FRANK P. BROWN,	REUBEN HAINES,	COLEMAN SELLERS,
JOHN H. COOPER,	JOHN HALL,	H. W. SPANGLER,
N. H. EDGERTON,	ARTHUR KITSON,	WILLIAM H. WAHL,

Elmer G. Willyoung.

Vacancies in the Committee on Science and the Arts, were filled by the election of Prof. L. M. Haupt, for the unexpired term of Mr. Hexamer, and Mr. C. O. C. Billberg in place of Mr. Hering.

Dr. Coleman Sellers followed with a paper on the "Priestman Engine."

Mr. Lockwood moved that the thanks of the meeting be tendered to Dr. Sellers and that the subject be referred to the Committee on Science and the Arts for investigation and report. Carried.

The Secretary's report embraced an account of a visit of inspection to the works of the Tacony Iron and Metal Works at Tacony, Philadelphia, where the process of manufacturing wire glass, and of electro-plating with aluminum the extensive iron work of the tower of the new City Hall were observed.

Adjourned. WM. H. WAHL, *Secretary.*

* Retiring members in roman; new nominees in italics.

BULLETIN FOR THE MONTH OF JANUARY, 1893.

TO MEMBERS OF THE INSTITUTE:

The Annual Meeting will be held on

WEDNESDAY, JANUARY 18, 1893.

MR. GEORGE D. BURTON, of Boston, Mass., will describe his "System of Electrical Forgings," and will illustrate the subject with the aid of lantern slides and by the exhibition of specimens of work produced.

The annual election will be held in the Hall, on the day of the annual meeting, between the hours of 4 to 8 P.M. A list of the nominations made at the stated meeting of December, 1892, appears in the Proceedings of the Meeting. Members may obtain copies of the official ballots at the Librarian's desk.

Special Notice.—The attention of members is specially directed to the fact that by resolution of the Board of Managers approved September 14, 1892, the *Journal* will be distributed to all *members in good standing*, without present increase of annual dues, beginning with the impression for January, 1893. This impression will be distributed to all members, whether in arrears or not. To ensure the regular transmission of the *Journal*, and also to avoid unnecessary addition to the clerical labor of the Actuary's office, delinquent members are urgently requested promptly to remit the amount of their annual dues.

SCHEDULE OF MEETINGS.

Committee on Science and the Arts,	Wednesday, Jan. 4, 8 P. M.
" Library,	Monday, Jan. 9, 4 P. M.
" Meetings,	Wednesday, Jan. 11, 7.30 P. M.
Board of Managers,	Wednesday, Jan. 11, 8 P. M.
Chemical Section,	Tuesday, Jan. 17, 8 P. M.
Institute,	Wednesday, Jan. 18, 8 P. M.
Electrical Section,	Tuesday, Jan. 24, 8 P. M.

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for June, 1891.*

County.	Station.	Elevation above sea level (feet.)	Barometer Reduced to Sea Level.			Temperature.													Relative humidity.	Dew point.	Precipitation.			Number of days			Wind.			Observers.
							Maximum.		Minimum.				Daily Range.													Prevailing direction.			
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of maximum.	Mean of minimum.	Mean.	Greatest.	Date.	Least.	Date.				Total inches.	Snow fall.	Number of rainy days.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.	
Allegheny,*	Pittsburg,	847	29.960	30.230	29.620	72.3	96	15	50	8	82.1	62.5	17.5	30	25	5	27	68.8	60	3.80	...	10	11	7	12	NW	...	NW	Oscar D. Stewart, Ob. W'th. Bu.
Bedford,	Charlesville,	1,300				68.	97	15	40	9	79	54	25	41	28	5	6	84	64	4.42	...	12	12	6	12	N	N	N	Miss E. A. G. Apple.
Berks,*	Hamburg,	380				70.4	96	17	42	8	83.6	57.2	26.4	61	14	6	18	...	...	2.25	...	8	10	13	7	NW	N	NW	William Shipe.
Berks,†	Reading,	280																											
Blair,	Altoona,	1,181				72.5	95	15	48	8, 9	83.5	62.5	10	30	37	6	7	...	...	7.73	...	11	...	...	...	...	...	...	Franklin Yeager.
Blair,	Blue Knob,	2,500																											Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947				68.														6.20		12	11	9	10	SW	NW	NW	A. H. Boyle.
Bradford,	Wysox,	718	29.960	30.290	29.695	68.7	96	15	39	9	83	54	29	45	28	7	7	76	61	4.91	...	12	16	5	9	E	W	E	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400				66.2	96	15	33	6	80.4	52.1	28.3	49	9	7	21	76.1	57.5	3.49	...	11	14	6	10	SE	SE	SE	Charles Beecher.
Bucks,	Forks of Neshaminy,					67.8	95	16	40	5	77	58.9	18.1	30	10	2	21	...	...	4.75	...	11	13	8	9	SW	SW	SW	George W. T. Warburton.
Bucks,	Quakertown,																												J. C. Hillsman.
Cambria,*	Johnstown,	1,184	30.006	30.273	29.646	68.1	97	16	43	9	81.7	53.9	27.8	40	14	9	21	75.1	59.1	4.71	...	11	13	12	5	SW	SW	SW	J. L. Hescock.
Cameron,	Emporium,	1,080					94	15	45	9								86.5	62.3	9.32	...	14	8	10	12				E. C. Lorentz.
Carbon,	Manch Chunk (27 days).	550				67.9	96	14	39	28	83.6	53.2	29.4	45	14	10	19	...	...	4.43	...	13	15	8	7	NW	NW	NW	T. B. Lloyd.
Centre,	State College,	1,191	29.931	30.271	29.618	67.5	95	15, 16	40	8	81.3	54.1	27.2	41	14	7	19	...	...	4.25	...	11	16	9	5	NW	NW	NW	John J. Boyd.
Chester,*	West Chester,	455	30.007	30.218	29.753	66.8	94	15	39	8	77.8	56.1	21.7	35	28	8	21	73.7	57.7	4.34	...	14	10	12	8	W	S	NW	Prof. Wm. Frear, Agr. Exp. Sta.
Chester,	Coatesville,	380				69.4	95	16	46	8	69.8	59.8	10	38	8, 25	7	19	72	59	4.17	...	13	20	4	6	NW	NW	S	Jesse C. Green, D. D. S.
Chester,	Kennett Square,	369				68.9	95	16	39	8	83.1	56.2	26.9	39	8	11	18	...	...	5.60	...	12	14	9	7	W	W	W	W. T. Gordon.
Chester,	Phœnixville,	275				68.	94	15	50	7										3.98	...	10	16	7	7	NW	...	SE	Benjamin P. Kirk.
Chester,	Westtown,	183	29.983	30.236	29.740	69.7	94	16, 26	42	8	81.9	57.8	24.1	36	15, 20	2	6, 12, 26	76.8	61.8	3.19	...	13	19	4	7	NW	NW	SW	Knowles Croskey.
Clarion,	Rimersburg,	350	30.008	30.223	29.742	69.5	92	15	42	8	79.7	59.4	20.3	32	8	7	19	...	...	4.43	...	7	14	8	8	W	W	W	Prof. Wm. F. Wickersham.
Clarion,	Clarion,	1,500				69.9	97	15	48	5, 7	77.6	62.2	15.4	26	13	5	16	...	...	...	...	...	14	9	7	W	W	W	Rev. W. W. Deatrick, A. M.
Clearfield,	Grampian Hills,	1,450																											C. M. Thomas, B. S.
Clinton,	Lock Haven,	560				67.9	90	14	46	7	79.7	60.1	19.6	33	9	6	17	...	...	3.71	...	13	10	10	10	E	W	E, W	Nathan Moore.
Columbia,	Catawissa,	560				68.5	97	15	42	8	81.3	55.4	25.9	40	14	6	7	...	...	4.35	...	13	11	10	9	W	W	W	Prof. John A. Robb.
Crawford,	Meadville,	1,300																											Robert M. Graham.
Cumberland,	Carlisle,	480				65.5	97	15	40	5	77	55.1	21.9	46	13	10	6	82	59.5	3.36	...	10	16	7	7	N	S	N	J. & B. H. Metcalf.
Dauphin,*	Harrisburg,	361	29.985	30.261	29.731	69.4	97	17	41	8	82.7	57.8	24.9	39	9, 29	8	19	83.7	64.2	3.46	...	13	9	13	8	E	W	W	J. E. Pague.
Delaware,	Swarthmore College,	190				70.1	93	15	43	8	79.8	50.1	19.7	31	8	7	18	70.2	56.9	3.76	...	13	14	9	6	W	W	W	Frank Ridgway, Ob. W'th. Bu.
Erie,*	Erie,	681	29.900	30.300	29.600	69.4	92	26	44	10	80.4	58.4	22	35	10	8	19	...	...	9.30	...	...	...	...	...	...	...	...	Prof. Susan J. Cunningham.
Fayette,	Uniontown,	1,000				66.	96	15	44	5	73	59	14	39	29	6	18	71	57	1.22	...	8	11	5	14	W	...	W	Peter Wood, Ob. W'th. Bu.
Franklin,*	Chambersburg,	618				71.6	91	17	48	28	71.9	61.9	10	33	28	8	7	...	...	8.63	...	11	15	9	6	SW	SW	SW	Wm. Hunt.
Fulton.	McConnellsburg,	875																											Miss Mary A. Ricker.
Huntingdon,*	Huntingdon,	650				68.5	94	15, 16	42	9	81.0	56.9	25	41	29	5	7	78.3	60.9	6.23	...	13	10	13	7	W	W	W	Thomas F. Sloan.
Indiana,	Indiana,	1,350				68.6	96	15	40	9	81.6	55.7	25.9	40	9	7	7	...	...	4.15	...	8	21	3	6	W	W	W	Prof. W. J. Swigart.
Lancaster,	Lancaster,	413																											Prof. S. C. Schmucker.
Lawrence,	Newcastle,	932																											Lewis T. Lampe.
Lebanon,	Lebanon,	474	29.994	30.258	29.743	72.8	94	15	34	12	81.8	54.4	27.5	45	12	28	3	...	...	3.92	...	10	10	7	13	S	E	E	Wm. T. Buts.
Lehigh,	Coopersburg,	520				68.3	95	16	40	8	81.5	55.7	25.8	39	25	8	7	77.1	61.1	3.40	...	11	13	10	7	SW	SW	SW	George F. Hayes, C. E.
Luzerne,	Drifton,	1,655				69.3	95	16	46	8	80.2	58.1	22.1	30	14, 30	6	7	...	...	2.53	...	12	15	9	6	SW	SW	NE	M. H. Boye, M. D.
Luzerne,*	Wilkesbarre,	575																											H. D. Miller, M. D.
Lycoming,*	Mashet,	550				70	96	15, 16	43	6	83.6	56.5	27.1	40	14	7	21	...	...	3.88	...	13	19	1	10	NE	...	...	A. W. Setterly.
McKean,	Smethport,	1,500				68.3	94	15	48	7										5	...	9	15	6	9	W	W	W	J. S. Gibson, P. M.
Mercer,*	Greenville,	1,000	29.904	30.161	29.529	68.6	92	15	35	28	79.6	51.6	20	44	28, 29	6	4	...	...	5.66	...	12	11	10	9	S	S	S	Armstrong & Brownell.
Montgomery,	Pottstown,	150				67.9	88	16	41	5	79.8	56	25.8	38	13	10	7	75.7	60.3	6.72	...	13	15	8	7	S	S	S	Prof. S. H. Miller.
Northampton,	Bethlehem,	360				72	99	16	47	8	86.8	59.7	25.1	33	8	5	18	75.5	61.4	4.30	...	7	30	5	5	W	W	W	Charles Moore, D. D. S.
Philadelphia,*	Philadelphia Weather Bureau.	117	29.967	30.229	29.730	71.8	96	17	49	7	81.8	61.8	20	38	8	6	18	68	58	2.51	...	7	15	7	8	SW	SW	SW	Lorch & Rice.
Philadelphia,	Philadelphia,	120	29.975	30.240	29.740	72.4	96	16	48	8	83.1	61.7	21.4	30	8	6	19	75.1	61.6	3.45	...	8	14	9	7	NW	SW	SW	Luther M. Dey, Ob. W'th. Bu.
Schuylkill,	Girardville,	1,000	29.966	30.170	29.734	67.2	92	15, 16	40	8	78.9	55.3	23.6	36	14	9	19	...	...	3.30	...	10	23	4	3	W	W	NW	John Comly.
Snyder,	Selinsgrove,	445	29.953	30.216	29.682	69.6	99	16	42	7	81	42.8	38.2	52	5	27	4	84	68.7	4.74	...	8	14	9	7	NW	SW	SW	E. C. Wagner.
Somerset,	Somerset,	2,250					94	16	39	7	81	42.8	38.2	52	5	27	4	84	68.7	4.74	...	8	14	9	7	NW	SW	SW	J. M. Boyer.
Sullivan,	Eagle's Mere,	2,000				66.7	89	15	43	9	80.4	53.7	26.7	43	28	13	7	75.8	61.2	5.30	...	10	8	7	15	SW	SW	SW	W. M. Schrock.
Tioga,	Wellsboro,																												E. S. Chase.
Union,	Lewisburg,	1,327	29.960	30.306	29.670	61.5	92	15	33	8	77.2	49.1	23.1	40	8	10	19	66.5	48.8	4.07	...	13	10	10	10	N	NW	SW	H. D. Deming.
Warren,	Columbus,	450				71	90	15	42	8	84.7	57.3	27.4	43	29	8	7	...	...	5.31	...	9	16	8	6	W	W	W	F. O. Whitman.
Washington,	Canonsburg,	1,410				65.5	92	15	32	5, 8	79.6	50.9	28.7	50	13	10	4	61.2	50.5	3.33	...	11	14	9	7	NE	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	950																											A. L. Runion, M. D.
Wayne,	Honesdale,	1,100				63.7	93	16	33	8	77.9	49.6	28.1	44	8	3	21	...	...	1.85	...	10	16	6	8	NW	NW	NW	Theodore Day.
Westmoreland,	Ligonier,	1,000				65.	90	15, 16	39	8	76.9	53.1	23.8	36	6, 10, 14	21	4	...	...	1.45	...	9	...	...	...	...	...	...	John Torrey.
Wyoming,*	South Eaton,	1,750				70.9	92	15	40	28	83.o	53.9	29.6	44	28	9	5	80.7	64	6.27	...	9	17	9	14	...	...	...	J. T. Ambrose.
York,*	York,	660				68.2	92	15	43	6	77.8	54.6	23.2	36	14	3	21	...	...	2.77	...	9	18	5	7	NW	NW	NW	Benj. M Hall.
Delaware,	Boothwyn,	386	29.962	30.207	29.681	69.8	96	16	42	8	82.6	57	25.6	38	29	11	19	...	...	3.86	...	13	14	9	7	NW	NW	NW	Mrs. L. H. Grenewald.
			29.907	30.160	29.620	71.3	95	17	43	7	81.7	58.1	25.6	38	8	2	19	...	...	5.58	...	8	17	7	6	E	SW	SW	Wm. S. Morrison.

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. Dey, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for July, 1891.*

County.	Station.	Elevation above sea level (feet).	Barometer Reduced to Sea Level.			Temperature.												Relative humidity.	Dew point.	Precipitation.			Number of Days.			Wind.			Observers.
							Maximum.			Minimum.			Daily Range.												Prevailing Direction.			
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of maximum.	Mean of minimum.	Mean.	Greatest.	Date.	Least.	Date.			Total inches.	Snowfall.	Number of rainy days.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.	
Allegheny,*	Pittsburg,	847	30.040	30.10	29.82	70	89	14	52	26	79.9	60.3	19.7	28	12	7	18	64.4	57.2	7.65	. . .	17	10	13	8	NW	NW	NW	Oscar D. Stewart, Ob. W'th. Bu.
Bedford,	Charlesville,	1,300				66.3	87	14	43	9	78.3	54.3	24.1	37	12	8	1	87.3	62.8	6.61	. . .	13	6	19	6	SW	SW	SW	Miss E. A. G. Apple.
Berks,*	Hamburg,	380				69	92	14	49	11	80.3	57.7	22.6																William Shipe.
Berk, †	Reading,	250				72.2																							Franklin Yager.
Blair,	Altoona,	1,181				70.7	90	15	43	15	80.8	60.6	20.2	35	12	7	25			7.35									Dr. Charles B. Dudley.
Blair,	Blue Knob,	2,500				65.9	89	13	50	9	76.5	59.9	16.6	19	12	14	18			8.99		16							A. H. Boyle.
Blair,	Hollidaysburg,	947				67.9	92	14	43	30	82.1	54.7	27.4	48	13	10	1,18	76.5	60	6.30	. . .	13	7	17	6	NW	NW	NW	Prof. J. A. Stewart.
Bradford,	Wysox,	718	30.040	30.32	29.78	68.1	91	14	41	10	77.7	54.2	23.5	43	23	5	13	75.6	53.3	4.98	. . .	11	13	5	8	W	W	W	Charles Boecher.
Bucks,	Forks of Neshaminy,					70.7														2.63	. . .	10	11	8	12	E	S	SW	J. C. Hilsman.
Cambria,*	Johnstown,	1,194	30.003	30.35	29.83															4.44	. . .	9	14	4	13	NW	W	W	E. C. Lorentz.
Cameron,	Emporium,	1,030				68.5	92	14			81.5							85.2	60.9	6.81	. . .	16	5	15	11				T. B. Lloyd.
Carbon,*	Mauch Chunk,	550				66.9	90	10										72.1	58	8.46	. . .	12	12	8	11	NW	W	W	J. J. Boyd.
Centre,	State College,	1,191	29.900	30.29	29.60	65.4	86	14	47	9,10	75.2	56	19.2	33	12	5	1	73.6	56.2	7.68	. . .	11	13	7	11	NW	W	NW	Prof. Wm. Frear.
Chester,*	West Chester,	435	30.033	30.34	29.77	69.1	87	15	53	5,9	78.3	61.1	17.1	27	12	6	2	75		5.65	. . .	15	8	14	9	W	W	W	Jesse C. Green, D. D. S.
Chester,	Coatesville,	380				71.5	90	15	49	11	80.3	56.3	22.1	34	12, 13	7	2			10.11		17	14	7	10	NW	SE	E	W. T. Gordon.
Chester,	Kennett Square,	275				67.9	91	14	40	9	77	52.9	25.1	42	10	10	18			11.61		16	11	11	9	W	W	W	Prof. Wm. F. Wickersham.
Chester,*	Phœnixville,	183	30.040	30.36	29.97	70.5	87	14	53	7	79.6	60.6	19	31	7	5	30	80.2	63.5	10.21	. . .	19	10	12	9	NW	. . .	SE	Benj. P. Kirk.
Chester,	Westtown,	350																		8.36	. . .	17	10	9	13	NW	. . .	SE	Knowles Croskey.
Clarion,	Rimersburg,	1,500																											Rev. W. W. Deatrick.
Clearfield,	Grampian Hills,	1,450	29.94	30.21	29.71	65.4	90	14	46	10	75.5	57.7	17.8	30	10	4	30			7.09		14	7	17	7	W	W	W	Nathan Moore.
Crawford,	Meadville,	1,300	29.97	30.26	29.76	64.1	86	14	39	27	76.1	51.6	24.5	43	12	11	18			2.77		7	9	16	6	S	W	W	B. H. Metcalf.
Cumberland,	Carlisle,	480				67.6	93	14	50	10	81.3	56.8	24.5	38	14	14	10	86	63	6.08	. . .	15	8	7	7				J. E. Pague.
Dauphin,*	Harrisburg,	361	30.033	30.34	29.74	69.6	87	14, 15	52	5	78.9	60.6	18.3	29	12	9	1	71.9	50.6	8.40	. . .	14	10	11	10	W	. . .	W	Frank Ridgway, Ob. W'th. Bu.
Delaware,	Swarthmore College,	190				69.4	86	21	54	9	78.8	60.8	18.0	29	13	6	2						10	10	11	SE	SE	NW	Prof. Susan J. Cunningham.
Erie,*	Erie,	681	30.000	30.30	29.75	65	87	13	47	27	73	59	14	23	27	5	8	66	55	2.66	. . .	11	13	10	9	S	. . .	S	Peter Wood, Ob. W'th. Bu.
Fayette,	Uniontown,	1,000				68.7	90	14	46	26	79.5	58.5	21	30	22	5	8			5.75	. . .	10	19	8	4				Wm. Hunt.
Fulton,	McConnellsburg,	875				68.1	90	14	46	29	81	56.7	24.3	40	12	5	1	77.2	60.5	6.32	. . .	12	14	10	7				T. F. Sloan.
Huntingdon,	Huntingdon,	650				68.1	97	14	44	19	81	55.1	25.3	39	14	8	1			4.49	. . .	12	11	8	12	W	W	W	Prof. W. T. Swigart.
Lawrence,	Newcastle,	932				67.9	91	14	40	9	77	52.9	25.1	42	10	10	18			4.40	. . .	12	8	14	9	W	W	W	W. T. Buts.
Lebanon,	Lebanon,	474	30.053	30.32	29.78	68.1	89	14	49	10	79.7	57.4	22.3	35	12	10	18	80	61.9	8.70	. . .	14	9	12	10	NE	SW	SW	Geo. F. Hayes, C. E.
Lehigh,	Coopersburg,	530				68.1	88	15	52	11	77.8	50.5	18.3	32	12	7	30			6.07	. . .	14	8	13	11	SW	SW	SE	M. H. Boyer, M. D.
Luzerne,*	Wilkesbarre,	575				68.1	97	15	45	17	79.3	56.9	22.4	43	17	12	18			6.28	. . .	11	15	5	11	NE	. . .	SW	A. W. Betterly.
McKean,	Smethport,	1,500				64.6	89	14	39	10	76.2	51	25.2	41	10	8	18						14	14	7	9	S	S	S	Armstrong & Brownell.
Montgomery,	Pottstown,	150				71.1	91	14	53	11	81.5	61.4	20.1	34	13	7	2	79.3	62.6	6.91	. . .	12	17	5	9	W	W	W	Chas. Moore, D. D. S.
Philadelphia,	Weather Bureau,	117	30.035	30.36	29.77	71.9	89	15	54	8	80	63.8	26.2	28	13	3	8	71.1	59.7	4.65	. . .	13	9	6	16	NW	. . .	NW	L. M. Dey, Ob. W'th. Bu.
Philadelphia,	Girardville,	130	30.040	30.36	29.76	72.4	91	15	54	9	81.4	63.2	18	25	13	6	2	77.7	63	5.89	. . .	14	9	7	15	NE, NW	. . .	SE, SW	John Comly, 1839 Centennial av
Schuylkill,	Selinsgrove,	445	30.010	30.28	29.83	68.5	90	14	40	31	80.6	49.8	31.3	39	21	21	8	85.8	70	6.69	. . .	10	15	7	9	SE	NE	NE	J. M. Boyer.
Snyder,	Somerset,	2,250				64.4	88	12, 13	40	9, 10	77.1	51.5	25.6	46	12	8	1	86.1	65.1	4.08	. . .	10	17	4	9	NW	NW	NW	W. M. Schrock.
Somerset,	Somerset,	2,250				64.4	88	12, 13	40	9, 10	77.1	51.5	25.6	46	12	8	1	86.1	65.1	4.08	. . .	10	17	4	9	NW	NW	NW	W. M. Schrock.
Tioga,	Wellsboro,	1,337	29.900	30.34	29.65	60.1	86	14	34	10	78.3	50	28.3	36	10	9	1	60.3	50.4	3.43	. . .	17	4	15	12	N	NW	NW	H. D. Deming.
Union,*	Lewisburg,	450				70.1	96	15	43	12	83.2	57	26.2	42	11	11	2			5.06	. . .	14	13	12	6	SW	SW	SW	F. O. Whitman.
Warren,	Columbus,	1,410				63.6	88	12	34	27	75.5	49.7	25.8	46	10	5	18	64.5	49.8	5.34	. . .	13	11	15	5	SW	SW	SW	William Loveland.
Wayne,	Dyberry,	1,100				63	90	13	40	28	75.3	50.2	25.1	42	6	6	3			3.98	. . .	13	10	9	12	W	W	W	Theodore Day.
Wayne,	Honesdale,	1,000				64.4	85	13	41	11	75	53.7	22.3	34	11	9	30	65	58.1	4.71	. . .	14							John Torry.
Westmoreland,	Ligonier,	1,150				60.2	89	14	41	10	80.2	53.2	27	42	11, 15	15	1	86	70	5.96	. . .	11	19	8	4				J. T. Ambrose.
Wyoming,	South Eaton,	660				65.6	86	14	45	10	75.3	56	19.3	33	12	5	18			4.88	. . .	12	10	11	10	S	. . .	S	B. M. Hall.
York,*	York,	385	29.993	30.26	29.79	70	90	14	50	10, 26	82	58.1	24.9	36	7	11	2	82.1	62.6	10.77	. . .	15	6	11	4	NW	. . .	NW	Mrs. L. H. Grenewald.
Bucks,	Rush Valley,	536	30.040	30.34	29.81	67.3	90	14, 15	46	11	79.9	55.6	24.3	36	13	12	2			7.29	. . .	15	8	12	11	NW	NW	NW	J. L. Heacock.
Bradford,	Le Roy,					70.7														4.44	. . .	9	14	4	13	N	W	W	
Clinton,	Lock Haven,	1,400				67.5	88	13, 14	48	31	74.8	59.6	15.3	27	23	4	1, 18			3.05	. . .	13	9	13	9	SW	SW	SW	G. W. T. Warburton.
		500				67.9	92	14	45	10	79	56	23	39	12	5	1, 2, 18			6.95	. . .	13	10	15	6	W	W	W	Prof. J. A. Robb.

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. Dey, *Ass st ant Director,*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for August, 1891.*

County.	Stations.	Elevation above sea level (feet).	Barometer reduced to sea level.			Temperature.												Relative humidity.	Dew point.	Precipitation.			Number of days			Wind.		
							Maximum.		Minimum.				Daily range.													Prevailing direction.		
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of maximum.	Mean of minimum.	Mean.	Greatest.	Date.	Least.	Date.			Total inches.	Snowfall.	Number of days rainfall.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.
Allegheny,*	Pittsburg,	847	30.01	30.23	29.62	71.7	94	10	48	29	81	62.4	18.6	28	7	7	23			1.60		11	7	14	10	NW		NW
Bedford,	Chariesville,	1,300				67.5	90	9	40	29	79.3	57.5	22	31	8	12	21			5.51		12	10	14	7	SW	SW	SW
Berks,*	Hamburg,	430				71.3	97	10	50	29	81.4	61.2	20.2	31	14, 17	7	5			6.30		10	8	11	13	W		
Blair,†	Altoona,	1,181				72.7	95	12	50	29	81.5	63.9	17.6	23	5, 30	9	4			3.13		10						
Blair,	Blue Knob,	2,500				66.5														5.40		14	8	16	7	NW	NW	NW
Blair,	Hollidaysburg,	947				68.5	94	10	39	29	83.8	54.5	29.8	38		16	4	79.5	62.0	4.26		12	11	14	6	S	W	S
Bradford,	Wyoz,	718				67	93	11	42	3, 29	78.4	56.1	22.3	37	1, 3	4	5	84.1	62.2	2.49		13	4	4	23	E	SW	SE
Bradford,	Le Roy,	1,400				68.6	90	11	47	29	76	60.9	15.1	34	1, 3	6	4			4.33		13	3	17	11	SW	SW	SW
Bradford,	Forks of Neshaminy (Rush Valley),					72.5														4.90		12	7	8	16	N	NW	W
Bucks,	Quakertown (29 days),	536				71.2														8.02		14						
Cambria,*	Johnstown,	1,184				70.6	94	9, 10, 11	43	29	83.1	58.2	24.9	37	1	7	23			3.87		16	5	15	11	S	W, NW	S
Cameron,	Emporium,	1,030				67.6	92	9	43	29	79	56	23	36	1	11	21, 24			5.40		14	3	20	8	E		E
Carbon,*	Mauch Chunk,	550				67.9	93	10, 11	46	1	79.8	58.8	21	34	1	5	30			5.89		10				NW		NW
Centre,	State College,	1,191				68.3	92	11	45	30	78.4	58.4	20	36	1	9	23	77.8	59.3	5.40		16	7	17	7	NW	NW	NW
Chester,	West Chester,	455				71.5	92	10, 11	53	29, 30	79.5	64.9	14.6	22	17	6	18	81	65	8.85		16	10	8	13	NW	S	SW
Chester,	Coatesville,	380				71.2	97	11	51	1	83.4	63.1	20.3	34	17	8	3			4.06		12	8	10	13	W	S	SW
Chester,*	Kennett Square,	375				70.4	85	10	56	30										8.74		15	8	10	13	NW		NW
Chester,	Phœnixville,	183				72.8	94	10	52	29	80.7	64.8	15.9	24	14	6	5	85.8	67.2	8.37		14	6	7	18	NW		NW
Clearfield,	Grampian Hills,	1,450				67.5	91	10	44	29	77.7	59.5	18.2	36	22	4	23			4.06		11	6	17	8	W	W	W
Clinton,	Lock Haven,	560				69	95	10	45	29										4.40		11	10	12	9	W	W	W
Crawford,	Meadville,	1,300				66.7	92	9, 10															8	18	5			
Cumberland,	Carlisle,	480				70.8	96	11	49	29	82.7	62.1	20.6	28	10, 11	8	5	88.5	66.7	5.53		12	5	16	10	SW	W	W
Dauphin,*	Harrisburg,	361	30.00	30.24	29.74	71.2	92	10	54	29	80.2	64.2	16	24	17	6	5	76.8	63.1	5.20		11	6	12	13	E	E	E
Delaware,	Swarthmore College,	190				72.6	95	10	52	30										7.54								
Erie,*	Erie,	681	29.98	30.21	29.55	69	89	9	51	29	75.7	61.3	14.4	23	16	7	28	71.0	58	1.96		11	4	15	12	NE	NE	NE
Fayette,	Uniontown,	1,000				71	91	9, 10	45	29	80.6	60.5	20.1	27	8	7	21, 23			3.85		12	16	11	4			
Fulton,	McConnellsburg,	875				70.8	95	10	44	29	82.9	59.7	23.2	32	10	11	24	80.4	64.3	4.82		11	8	16	7			
Huntingdon,*	Huntingdon,	650				70.8	94	10	49	25, 30	82.3	59.2	23.1	34	14	11	24			3.53		11	14	8	9	W		W
Lebanon,	Lebanon,	474	30.02	30 26	29.71	70.4	94	10	47	29	81.2	60.9	20.3	33	11	8	5	85.9	66.2	5.06		12	8	9	14	SW	SW	SW
Lehigh,	Coopersburg,	509				69.9	94	11	52	1, 3	78.5	62.6	16.2	30	1	4	5			7.16		14	6	8	17	SE	SW	NW
Luzerne,	Wilkesbarre,	575					96	10	45	29										3.46		8	18	5	8	NE		SW
McKean,	Smethport,	1,500				65.8	90	10	43	29	78.6	54.1	24.5	36	17	11	24			5.15		7	15	7	9	S	S	S
Montgomery,	Pottstown,	150				74.1	96	11	54	29	82.7	65.6	17.1	27	1	5	18	84.0	67	7.01		12	11	11	9	W	W	W
Philadelphia,*	Philadelphia Weather Bureau,	117	30.00	30.24	29.71	74.3	97	10	54	30	83	60.6	15.4	25	10	7	18	77.0	64	4.22		14	6	11	14	SW	SW	SW
Philadelphia,	Philadelphia (Centennial avenue),	120	30.01	30.24	29.72	74.5	96	10	54	30	83.4	66.5	15.9	26	10	6	5	83.3	67.1	5.30		14	5	13	13	SW	SW	SW
Schuylkill,	Girardville,	1,000	29.96	30.16	29.70	67.9	89	10	38	16	76	58	18	47	14	8	30			9.47		10	9	11	11	W	W	W
Snyder,	Selinsgrove,	445	29.90	30.23	29.53	69	95	10	40	29	83.4	50.5	31.9	37	3	26	16	88.2	66.7	7.18		12	8	10	13	SW	NW	NW
Somerset,	Somerset,	2,250				66.4	88	10	35	30	80.6	54.5	26.1	41	1	12	21	88	62	5.02		15	7	10	14	NW	NW	NW
Tioga,	Wellsboro,	1,327		30.26	29.61	67.4	86	10	36	30	74.3	60.2	24.1	36	30	8	21	67.4	56	3.57		13	10	15	8	N	N	SW
Union,	Lewisburg,	450				71.2	95	10	47	29	82.7	59.8	22.9	33	1	8	24			9.42		6	7	15	9	SW		SW
Warren,	Columbus,	1,410				65.6	94	9	38	30	78	53.7	24.3	38	7	5	21	66	52	3.74		13	10	8	12	SW	SW	SW
Wayne,	Dyberry,	1,100				65	94	11	40	1	77.6	56.6	24	43	17	8	30			4.75		14	5	14	12	NW	W	SW
Wayne,	Honesdale,	1,060				67.5	88	11	44	3	77.2	57.8	19.4	33	17	7	30	68.4	64.5	2.21		12						
Westmoreland,	Ligonier (27 days),	1,150				68.9	92	10	40	29	82.3	55.5	26.8	39	16	9	24	77	69	2.81		8						
Wyoming,*	South Eaton,	960				67.7	89	11	47	29	76.4	58.9	17.5	31	17	7	5			4.15		11	5	15	11	S		NW
York,	York,	385	29.96	30.22	29.68	71.2	95	10	48	29	83	60.6	22.4	35	17	16	5	86.5	66.9	3.29		11	8	16	7	NW		NW
Lawrence,	New Castle,	982				72.2	95	10	38	29	81.6	54.1	27.5	38	27	12	21			1.43		6	6	18	7	SE	NW	SE

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. Dey, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for September, 1891.*

County.	Station.	Elevation above sea level (feet).	Barometer Reduced to Sea Level.			Temperature.													Relative humidity.	Dew point.	Precipitation.		Number of days			Number of rainy days.	Wind.			Observers.
							Maximum.		Minimum.				Daily Range.														Prevailing Direction.			
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of maximum.	Mean of minimum.	Mean.	Greatest.	Date.	Least.	Date.				Total inches.	Total snowfall during month.	Clear.	Fair.	Cloudy.		7 a. m.	2 p. m.	9 p. m.	
Allegheny,*	Pittsburg,	847	30.18	30.42	29.98	69.4	90	2	46	9	79.7	59	30.7	39	30	5	6	76	59.3	1.90	. . .	15	10	5	7	NW	NW	NW	G. D. Stewart, Ob. W'th. Bu.
Bedford,	Charlesville,	1,300				63.1	88	18	37	9	78.1	51.1	27	38	18	10	5	81.8	58.1	4.55	. . .	16	8	6	7	N	SW	SW	Miss E. A. G. Apple.
Berks,†	Hamburg,	380				66.7	94	26	43	9	80.5	57.5	23.2	38	17	9	5	. .	. .	1.77	. . .	9	16	5	8	NW	SW	SW	Wm. Shipe.
Berks,	Reading,	280	30	30.33	29.76	65.8	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	1.57	. . .	. .	. .	. .	8	. .	. .	. .	F. Yager.
Blair,	Altoona,	1,181				69.2	86	27, 28	47	10, 30	78.6	59.6	18.6	36	26	5	6	. .	. .	2.71	. . .	. .	. .	. .	7	. .	. .	. .	Dr. C. B. Dudley.
Blair,	Blue Knob,	2,500				62.9	84	17, 18, 22	36	9, 10	. .	. .	. .	. .	. .	. .	. .	. .	. .	2.70	. . .	16	6	4	5	SW	SW	NW	A. H. Boyle.
Blair,	Hollidaysburg,	947				64.5	91	17, 26	36	9, 30	81	50	31	43	17	9	5	78.8	56	2.16	. . .	22	4	4	5	S	W	S	Prof. J. A. Stewart.
Bradford,	Wyeox,	718	30.16	30.44	30.91	64.1	87	18	37	9	76.2	52.3	23.9	37	17	8	5	86	50.9	1.79	. . .	16	5	9	4	E	SW	SE	Charles Beecher.
Bradford,	Le Roy,	1,400				65.3	87	25	42	30	78.3	56.4	17.9	31	17	9	6	. .	. .	2	. . .	15	10	5	8	SW	SW	SW	G. W. T. Warburton.
Bucks,	Hulmeville,		30.09	30.35	29.80	66.5	90	26	43	10, 11	79.1	56.7	22.4	30	17	10	6	. .	. .	2.71	. . .	15	12	3	4	S	S	S	L. Townsend.
Bucks,	Forks of Neshaminy (Rush Valley),					66.5	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	3.09	. . .	14	13	2	6	N	N	W	J. C. Hilsman.
Bucks,	Quakertown,	500																		1.17	. . .	. .	. .	. .	. .	. .	. .	. .	J. L. Heacock.
Cambria,*	Johnstown,	1,184	30.30	30.50	30.06	67.4	92	17, 21	43	9, 10	81.5	53.7	27.8	38	20	12	30	88.2	63.4	1.83	. . .	7	16	7	8	S	. .	S	E. C. Lorentz.
Cameron,	Emporium,	1,060				66.5	88	21	33	30	77.4	51.7	25.7	42	17	7	5	. .	. .	1.17	. . .	18	7	5	9	W	W	W	T. B. Lloyd.
Carbon,	Mauch Chunk (28 days),	550				66.4	91	18	40	10	78.2	54.5	23.7	43	18	9	5	. .	. .	1.87	. . .	17	8	5	6	. .	. .	. .	J. J. Boyd.
Centre,	State College,	1,191	30.12	30.39	29.83	65.4	86	21	40	9	76.2	54.9	21.3	33	17	6	5	74.8	56.2	2.30	. . .	18	8	8	8	W	W	W	Prof. W. Frear.
Chester,	West Chester,	455	30.14	30.41	29.87	68.2	90	26	46	9	77.7	60.6	17.1	26	17	8	8	. .	. .	4.30	. . .	25	3	4	8	NW	SW	SE	J. C. Greene. D. D. S.
Chester,	Coatesville,	380	. .	. .	. .	67.4	94	26	43	9	81.6	56.2	25.4	39	17	13	8	. .	. .	3.38	. . .	17	10	3	6	W	W	W	W. T. Gordon.
Chester,	Kennett Square,	275	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .	15	10	5	5	NW	. .	NW	B. P. Kirk.
Chester,	Phœnixville,	183	30.16	30.45	29.92	68.9	89	26	42	11	78.4	58.7	19.7	33	11	10	8, 29	85.6	63.5	2.67	. . .	13	13	5	6	NW	. .	SW	Knowles Croskey.
Clearfield,	Grampian Hills,	1,450				64	84	26	38	9, 10	75.8	55.5	20.3	36	10	6	6	. .	. .	2.38	. . .	16	9	1	5	. .	W	. .	Nathan Moore.
Clinton,	Lock Haven,	560				66	91	18	40	9	80 4	54.1	26.3	37	23	5	5	. .	. .	3.41	. . .	18	7	5	8	W	W	W	Prof. J. A. Robb.
Crawford,	Meadville,																												Prof. J. H. Montgomery.
Cumberland,	Carlisle,	480				68.4	92	26	43	10	82.6	57.2	25.6	36	17	11	5	85.6	64.2	1.95	. . .	16	11	3	6	NW	SW	W	J. E. Pague.
Dauphin,	Harrisburg,	361	30.16	30.43	29.93	69.4	88	26	50	10	78.7	60.2	18.5	30	17	5	29	76	59.4	1.75	. . .	13	11	6	8	W	W	W	F. Eldgway. Ob. W'th. Bureau.
Delaware,	Swarthmore College (28 days),	190	30.15	30.33	29.97	69.7	91	26	47	9	79.5	58.9	20.6	30	21	14	3	82.1	63.6	2.89	. . .	18	4	6	5	NW	W	. .	Prof. Susan J. Cunningham.
Erie,*	Erie,	681	30.13	30.40	29.91	66	86	17	48	11	73.8	58.7	14.1	25	11	4	6	74	56	2.82	. . .	14	9	7	11	S	S	S	Peter Wood, Ob. W'th. Bureau.
Fayette,	Uniontown,	1,000				68.6	88	24	41	9	78.6	58.3	22.3	30	10	11	6	. .	. .	2.23	. . .	23	4	3	8	. .	. .	. .	Wm. Hunt.
Fulton,	McConnellsburg,	875	. .	. .	. .	66	92	18	39	9	81.6	53.8	27.7	38	18	9	5	80.2	60	2.55	. . .	19	8	3	5	. .	. .	. .	Thos. F. Sloan.
Huntingdon,	Huntingdon,	650	. .	. .	. .	67.5	92	21, 25	39	9	81.4	53.9	27.5	41	17	11	6	. .	. .	3.07	. . .	22	5	3	5	W	W	W	Prof. W. J. Swigart.
Lancaster,	Lancaster (24 days, 7th to 30th),	413	30.17	30.40	29.87	67.3	89	22	46	30	79.3	55.5	23.8	31	21	10	8	79.6	60.4	.28	. . .	14	9	1	3	SW	SW	SW	L. T. Lampe.
Lawrence,	Newcastle	933	. .	. .	. .	69.6	91	21	36	10	78.6	58.6	28.8	39	2	9	29	. .	. .	3.54	. . .	19	8	3	6	SE	NE	S	W. T. Buts.
Lebanon,	Lebanon,	474	30.16	30.44	29.92	66.9	91	22, 26	40	9	80.3	55.5	24.8	40	18	12	5	82.9	61.2	1.07	. . .	11	11	2	8	NE	SW	SW	G. F. Hayes, C. E.
Lehigh,	Coopersburg,	530	. .	. .	. .	66.5	86	26	45	9	76.4	58.6	27.8	29	17	8	5	. .	. .	2.06	. . .	13	11	6	8	NE	SW	NE	Dr. M. H. Boye.
Luzerne,	Drifton,	1,655																											J. R. Wagner.
Luzerne,*	Wilkesbarre,	575	. .	. .	. .	65.8	91	26	44	10, 30	80.8	55.8	25	36	17	9	1	. .	. .	1.70	. . .	22	2	6	5	NW	. .	NW	A. W. Betterly, M. D.
McKean,	Smethport,	1,500	. .	. .	. .	60.8	89	18	37	30	74.1	47.6	27.5	45	17	8	4	. .	. .	2.45	. . .	22	4	4	7	SW	SW	SW	Armstrong & Brownell,
Montgomery,	Pottstown,	150	. .	. .	. .	70.1	90	26	47	9	80.5	59.8	30.7	32	17	8	5	80.4	61.9	2.03	. . .	22	4	4	4	W	W	W	Chas. Moore, D. D. S.
Philadelphia,*	Philadelphia Weather Bureau,	117	30.16	30.42	29.88	71.6	91	26	51	9	80.5	63	17.5	26	18	6	8	76.9	60.6	1.90	. . .	17	7	6	7	NW	. .	. .	L. M. Dey.
Philadelphia,	Philadelphia (Centennial avenue),	120	30.16	30.42	29.88	71.6	91	18, 26	49	9	80.6	62.6	18	26	21	6	8	81.5	63.4	1.88	. . .	13	14	3	7	NW	SW	SW	John Comly.
Schuylkill,	Girardville,	1,000	30.12	30.54	29.97	64.4	94	18	41	9	74.6	54.1	20.5	35	18	8	20	. .	. .	1.99	. . .	19	9	2	6	W	W	W	E. C. Wagner.
Snyder,	Selinsgrove,	445	30.14	30.40	29.65	65.5	92	4	36	17, 19	80.5	45.9	34.6	52	18	14	29	86	63 4	4.12	. . .	20	7	3	8	NW	SE	NE	J. M. Boyer.
Somerset,	Somerset,	2,250	. .	. .	. .	62.2	94	17	33	9	79	49.2	29.8	45	17	15	5, 7	88.7	59.7	4.17	. . .	18	3	10	7	SW	SW	SW	Wm. Schrock.
Tioga,	Wellsboro,	1,537	30.12	30.46	29.86	60.8	86	19, 24	32	30	74.7	47	27.7	32	9	10	29	68.7	52.3	2.30	. . .	16	8	6	7	N	N	SW	H. D. Deming.
Union,*	Lewisburg,	450	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	2.60	. . .	19	7	4	4	W	W	W	F. O. Whitman.
Warren,	Columbus,	1,410	. .	. .	. .	62.8	88	17, 24	32	30	76.8	49.6	27	43	17	5	6	65	48	2.46	. . .	19	6	5	9	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	. .	. .	. .	60.8	87	21	34	9	76.1	49.3	26.8	43	17	4	5	. .	. .	2.37	. . .	13	13	4	6	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	. .	. .	. .	63.4	82	26	38	9	75.8	52.9	20.9	34	17	5	5	69.5	59	2.37	. . .	. .	. .	. .	7	. .	. .	. .	John Torry.
Westmoreland,	Ligonier,	1,750	. .	. .	. .	66.1	90	27	37	9	82	51.4	30.6	40	21	13	6	. .	. .	2.17	. . .	22	3	2	6	. .	. .	. .	J. T. Ambrose.
Wyoming,*	South Eaton,	660	. .	. .	. .	63.3	87	18	40	9	72.9	53.8	19.1	28	18	7	5	. .	. .	1.35	. . .	16	9	5	6	S	. .	S	B. M. Hall.
York,*	York,	385	30.13	30.34	29.96	69	92	26	40	9	81.8	56.2	25.6	39	17	6	29	88.1	67	1.88	. . .	21	6	3	6	NW	. .	NW	Mrs. L. H. Grenewald.

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. Dey, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for October, 1891.*

County.	Station.	Elevation above sea level (feet).	Barometer Reduced to Sea Level.			Temperature.													Relative humidity.	Dew point.	Precipitation.			Number of Days			Wind.			Observers.
						Maximum.			Minimum.				Daily Range.									Depth of Snow.						Prevailing Direction.		
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of maximum.	Mean of minimum.	Mean.	Greatest.	Date.	Least.	Date.			Total.	15th.	31st.	Number of days rainfall.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.	
Allegheny,*	Pittsburg,	847	30.14	30.53	29.72	53.4	85	3	31	28	62.6	44.2	18.4	33	25	6	8		66.6	40	1.53		T	10	9	14	8	W		W	O. D. Stewart, Obs. Weather Bureau.
Berks,	Hamburg.	380				52	89	3,4	24	29	62.4	41.5	20.9	35	30	7	20				2.69			8	6	14	11				William Shipe.
Berks,	Reading.	230																													F. Yager.
Blair,†	Altoona (26 days).	1,181				53.5	82	5	35	12	61.6	45.2	16.6	25	25, 29	7	13, 16		58.5	39	2.54										Dr. C. B. Dudley.
Blair,	Blue Knob.	2,500					80	3	33	28				17	4	8	22, 28				3.30		T	9	8	10	13	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg.	947				49	87	3	20	29	65	35	30	49	2	8	7		75.8	41.2	2.76			11	13	8	10	W	W	W	Prof. J. H. Stewart.
Bradford,	Wysox.	718	30.13	30.61	29.76	47.2	82	3,4	20	29	57.8	36.3	21.5	37	30	5	7		83.6	43.2	4.43			8	13	4	14	E	W	NW	Charles Beecher.
Bradford,	Le Roy.	1,400				48.1	83	3	25	12	57	39.2	17.5	33	1	4	7, 27				4.25	T		10	9	10	12	SW	SW	SW	G. W. T. Warburton.
Bucks,	Hulmeville,		30.06	30.54	29.61	51.5	86	4,5	26	29	62.6	41.9	20.7	38	5	4	12				2.91			5	12	8	11	NW	NW	NE	L. Townsend.
Bucks (27 days).	Forks of Neshaminy (Rush Valley).					51															3.68			9	13	9	5	N	N	W	J. C. Hillaman.
Bucks,	Quakertown.	536	30.06	30.54	29.74	49.9	86	4	21	29	62.6	39	23.6	35	4	9	22		80.2	43.7	2.96		T	7	9	11	11	NE	NE, NW	NE	J. L. Heacock.
Cambria,*	Johnstown.	1,184	30.16	30.56	29.70	50.9	84	2	27	29	62.6	39.4	23.2	41	29	10	29				2.80		T	10	9	11	11	S		S	E. C. Lorentz.
Cameron,	Emporium.	1,020				48.2	85	3	23	29	59.9	36.5	23.4	41	30	6	20		46.5	29.7	3.48			8	11	7	13	W	E	W	T. B. Lloyd.
Carbon,*	Mauch Chunk.	550				47.1	86	4			60.6	36.8	21.8								2.89										J. J. Boyd.
Centre,	State College	1,191	30.06	30.57	29.67	48.7	83	3,4	21	29	57.9	39.5	18.4	34	30	5	7		73.7	39.6	4.38			12	7	11	13	W	W	W	Prof. W. Frear.
Chester,	West Chester.	455	30.06	30.57	29.67	52.2	84	4	26	29	62.6	44.2	18.4	28	30	10	19		70	42	3.40			11	15	4	12	NW	NW	NW	J. C. Green. D. D. S.
Chester,	Coatesville.	380				50.5	90	4	21	29	64.9	39.6	25.3	44	30	4	19				3.46			7	13	7	12	W		W	W. T. Gordon.
Chester,*	Kennet Square.	375				50.5															3.16			8	11	9	11	NW		NW	B. P. Kirk.
Chester,	Phœnixville,	183	30.10	30.53	29.69	53	86	3,4	25	29	63.5	42.5	21	34	30	9	20		79.8	44.9	3.23			9	8	7	16	NW		NW	Knowles Crosby.
Clearfield,	Grampian Hills.	1,450	30.20	30.58	29.80	46	80	4	24	29	55.4	36.5	16.9	36	25	2	7, 30				3.17			11	11	11	9	W	W	W	Nathan Moore.
Clinton,	Lock Haven,	560				50	89	4	25	29	61.4	38.7	22.7	37	31	4	20				3.73			13	12	10	9	W	W	W	Prof. J. H. Robb.
Crawford,	Meadville,	1,300				47.2																									Prof. J. H. Montgomery.
Cumberland,	Carlisle,	480				50.6	91	3	26	29	64.6	41.2	23.4	39	31	5	7, 19		83.4	45.8	3.51			8	12	7	12	N	N	N	J. E. Pague.
Dauphin,*	Harrisburg.	361	30.12	30.68	29.70	52.4	85	4	32	29	60.8	44.1	16.7	33	30	6	7		70.8	41.7	2.87			11	12	5	14	NW	NW	NW	F. Ridgeway, Obs. Weather Bureau.
Delaware,	Swarthmore College.	190	30.06	30.46	29.68	52.1	87	4	25	9	62.9	44.5	18.4	30	29	9	20		74.8	43.9	3.75			6	11	12	8	N	N	N	Prof. Susan J. Cunningham.
Erie,*	Erie,	681	30.08	30.58	29.69	53	83	4	30	12	58.5	44.6	13.9	28	25	5	5		68	40	1.75			11	8	8	15	S	S	S	Peter Wood, Obs. Weather Bureau.
Fayette,	Uniontown.	1,000				52.9	84	4	30	29	62.8	43	19.8	34	26	2	27				2.99		1	6	19	5	7				Wm. Hunt.
Fulton,	McConnellsburg.	875				50.6	88	3,4	33	29	62.6	38.9	23.7	44	30	7	7		79.1	45.8	3.39			4	15	6	10	N	N	NW	Thos. F. Sloan.
Huntingdon,	Huntingdon,	650				50.2	88	4	22	29	63	37.5	25.5	45	30	6	27				3.13			6	15	7	9	W		W	Prof. W. J. Swigart.
Lancaster,*	Lancaster—																														
	Franklin and Marshall College.	415	30.14	30.52	29.75	52	86	4	34	28	63.2	40.8	22.4	36	31	9	20		84.3	47	3.05			9	11	11	9	NW	NW	NW	L. T. Lampe.
Lawrence,	Newcastle,	962				54	86	3,4	24	28, 29	62.5	36.1	26.4	40	25	6	27				.84			8	12	7	12	SE	SE	SE	W. T. Butz.
Lebanon,	Lebanon.	474	30.11	30.57	29.73	50.7	90	4	25	29	64	40.7	23.3	37	31	6	7		78.7	44.5	3.14		T	10	11	9	11	SW	SW	SW	G. E. Hays, C. E.
Lehigh,	Coopersburg.	520				50.6	86	4	27	29	62.7	42.8	17.9	36	31	9	7				2.74			6	12	7	12	NW	NW	NE	Dr. M. H. Boye.
Luzerne,	Drifton.	1,655																													J. R. Wagner.
Luzerne,*	Wilkesbarre.	575				55.2	75	12	22	28	60.8	43.7	17.1	38	31	6	1				1.63			5	11	4	16	NW		NW	H. W. Betterly.
McKean,	Smethport.	1,500																													Armstrong & Brownell.
Montgomery,	Pottstown.	150				53.6	87	4	25	29	63.7	43.9	19.8	36	30	5	23		77.9	46	3.95			4	16	6	9	W	W	W	Charles Moore, D. D. S.
Philadelphia,*	Philadelphia Weather Bureau.	117	30.09	30.54	29.66	54.9	86	4	36	28	63.8	47	15.8	25	26	7	13		70.3	45.2	2.57			9	14	7	10	NW	NW	NW	L. M. Dey.
Philadelphia,	Philadelphia, Centennial avenue.	120	30.10	30.53	29.67	55.2	88	5	32	29	64.3	46.1	18.2	25	25, 26	9	20		78.8	46	3.19			10	11	12	8	NW	NE	NW	John Comly.
Schuylkill,	Girardville.	1,000	30.08	30.40	29.54	46	80	4	27	29	59.3	39.1	20.2	36	29	3	12				3.77			8	14	10	7	W	W	W	E. E. Wagner.
Snyder,	Selinsgrove.	445	30.11	30.54	29.83	50.3	79	5			62.5	40.8	21.5	36	31	7	19		84	46	4.46			9	13	11	8	NW	NW	NW	J. M. Boyer.
Somerset,	Somerset.	2,250				47.8	86	3,4	22	29	61.1	34.7	27.4	49	2	12	12		89.3	45.1	2.45			6	12	3	16	NW	NW	NW	Wm. Schrock.
Tioga,	Wellsboro.	1,337	30.08	30.61	29.74	44.2	82	4	18	19	51.4	35.7	15.7	38	29	5	27		83.2	68.4	2.44		T	5	5	15	11	N	NW	N	H. D. Deming.
Union,*	Lewisburg.	450				51.3	82	3	27	25	63.7	39.7	23	36	31	10	20				3.75			4	14	9	8	NE		NE	F. O. Whitman.
Warren,*	Columbus.	1,410				47	84	3,4	19	13	57.9	36	21.9	49	13	1	27				1.95			11				N	SW	SW	Wm. Loveland.
Wayne,	Dyberry.	1,100				44.1	82	4	15	29	56.8	33.6	23.2	43	31	5	7				3.41		T	8	8	12	11	NW	NW	NW	Theo. Day.
Wayne,	Honesdale.	1,000				47.4	78	4	19	29	57	37.9	19.1	39	30	4	7		61.1	40.5	3.74			4							John Torrey.
Westmoreland,	Ligonier,	1,750				50.5	87	4	21	29	63.5	37.2	26.3	44	29	4	27				.88			9	12	11	8				J. T. Ambrose.
Wyoming,*	South Eaton.	660				48.6	83	4	22	29	58.1	39.1	19	33	31	7	7				3.71			6	9	8	14	NW		NW	B. M. Hall.
York,*	York.	385	30.06	30.45	29.78	50.1	87	4	30	29	63.3	36.3	27	42	30	7	7		81.1	44.7	3.20		T	10	15	8	8	NW		NW	Mrs. L. H. Grenewald.

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. Dey, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for November, 1891.*

County.	Station.	Elevation above sea level (feet).	Barometer Reduced to Sea Level.			Temperature.												Relative humidity.	Dew point.	Precipitation.		Number of Days				Wind.			Observers.
						Maximum.		Minimum.				Daily Range.														Prevailing Direction.			
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of maximum.	Mean of minimum.	Mean.	Greatest.	Date.	Least.	Date.			Total.	Snow.	With rain.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.	
Allegheny,*	Pittsburg,	847	30.15	30.64	29.26	42.2	76	9	16	18	49.6	35	14.6	32	8	5	1	66	30.3	2.61	...	14	3	7	20	SE	...	SW	Oscar D. Stewart, Ob. W'th. Bu.
Berks,*	Hamburg,	380	...	...	...	39.6	63	23	13	30	49.5	30.1	19.4	35	8	7	29	...	...	1.43	...	6	5	13	12	...	...	...	Wm. Shipe.
Berks,†	Reading,	390	...	...	...	40.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Franklin Yager.
Blair,	Altoona,	1,181	...	...	...	44.9	69	1	11	30	53.6	36.3	17.4	37	20	5	23	80.3	31	1.89	...	9	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Blue Knob,	2,500	...	...	...	35.1	63	9	10	18	...	...	...	...	...	...	...	...	...	2.29	11	11	5	11	14	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg,	947	...	...	...	38.6	69	9	9	19	49.8	26.9	22.9	43	9	8	3	74.8	31.6	2.76	2.5	8	4	8	18	W	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	30.14	30.74	29.25	37.3	64	23	14	30	45.6	28.7	17.3	34	17	6	29	79.4	32.5	2.75	1	9	7	4	19	E	NW	SE	Charles Beecher.
Bradford,	Le Roy,	1,400	...	...	...	36.4	61	23	8	30	45.8	29.1	14.7	29	28	5	3	...	...	3.24	3	13	6	4	20	SW	SW	SW	Geo. W. T. Warburton.
Bucks,	Hulmeville,		30.19	30.85	29.29	41.6	66	10	15	30	51.6	31.3	20.3	33	12	8	9	...	...	2.92	...	4	15	5	10	NW	...	N	L. Townsend.
Bucks,	Forks of Neshaminy (Rush Valley),		...	...	...	42.8	...	...	...	...	...	...	...	...	...	...	...	...	...	2.04	...	9	14	7	5	N	N	N	J. C. Hilsman.
Bucks,	Quakertown,	536	30.18	30.79	29.30	38.6	66	12	10	30	50.7	27.1	23.6	37	8,9	14	29	87	33.5	2.31	...	10	8	17	5	SW	NW	NW	J. L. Heacock.
Cambria,*	Johnstown,	1,184	30.15	30.76	29.40	40.8	69	8	10	19	49.6	30.5	19.3	44	6	8	29	...	...	2.53	...	15	1	11	18	S,SW	...	S	E. C. Lorents.
Cameron,	Emporium,	1,030	...	...	...	38.8	66	9	9	19	47.3	29	18.3	37	9	8	27	76.3	32	4.01	2.5	12	7	3	20	W	W	W	T. B. Lloyd.
Centre,	State College,	1,191	30.12	30.76	29.16	37.5	62	11	9	30	45.6	28.4	17.2	40	17	6	3	77	30.4	2.91	2.8	7	2	11	17	W	W	W	Prof. Wm. Frear.
Chester,	West Chester,	455	30.17	30.79	29.28	41.1	65	10	12	30	50.6	32.9	17.7	33	17	7	5	70	31.5	2.29	...	11	17	3	10	NW	NW	NW	Jesse C. Green, D. D. S.
Chester,	Coatesville,	330	...	...	...	40.3	69	12	11	31	52.4	28.2	24.2	46	9	13	5	...	...	1.78	...	9	14	6	10	W	W	W	W. T. Gordon.
Chester,	Kennett Square,	375	...	...	...	40.1	...	...	...	...	...	...	...	...	...	...	...	...	...	2.39	...	11	13	5	13	NW	...	NW	Benj. P. Kirk.
Chester,	Phœnixville,	183	30.19	30.82	29.36	44.7	68	13	15	30	52	30.6	21.2	33	8,17	15	24	80.2	29.8	1.69	T	13	10	6	14	NW	...	NW	Knowles Croskey.
Chester,	Westtown (29 days),	350	...	...	...	42.2	65	10	14	30	50.9	33.6	17.3	32	17	6	27	...	...	1.41	...	...	...	...	...	...	...	...	T. H. Haines.
Clearfield,	Grampian Hills,	1,450	30.05	30.56	29.21	34.5	60	9, 16	8	19	43.6	28.1	14.5	34	17	4	1.5	...	...	3.35	6	14	3	13	15	W	W	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	39.4	67	9	10	30	47.7	28.9	18.8	39	9	5	5	...	...	2.72	...	9	13	4	13	W	W	W	Prof. John A. Robb.
Crawford,	Meadville,	1,300	...	...	...	38.8	70	9	9	19	47.5	30.2	17.3	39	17	5	3	...	...	...	...	...	5	10	15	...	...	...	E. C. Williams.
Cumberland,	Carlisle,	480	...	...	...	38.4	66	8, 10	13	30	50.7	30.3	20.4	42	8	5	5	84.5	34.5	1.70	2	10	11	9	10	SE	NW	NW	J. E. Pague.
Dauphin,*	Harrisburg,	361	30.19	30.82	29.39	41.1	68	23	14	30	48.9	33.3	15.6	32	17	5	29	69.1	30.3	1.95	...	12	8	13	9	W	...	W	Frank Ridgway, Ob. W'th. Bu.
Delaware,	Swarthmore College,	100	30.16	30.72	29.49	41	67	10	13	30	52.4	32.5	19.9	30	17	12	24, 26	77.3	34.9	1.62	...	6	14	6	10	NW	NW	NW	Prof. Susan J. Cunningham.
Erie,*	Erie,	691	30.06	30.60	28.92	40	73	9	18	19	46.2	33.7	13.5	24	23	4	14	73	31	3.90	...	20	2	6	22	S	...	S	Peter Wood, Ob. W'th. Bu.
Fayette,	Uniontown,	1,000	...	...	...	42.5	70	16	17	19	50.9	34.2	16.7	32	9,16	5	5	...	...	3.05	...	10	11	10	9	...	...	...	Wm. Hunt.
Fulton,	McConnellsburg (23 days),	875	...	...	...	41.8	63	9	13	19	51.8	29.3	22.5	38	8	6	5	78.8	35.6	3.03	2	5	10	6	7	W	NW	W	Thomas F. Sloan.
Huntingdon,*	Huntingdon,	650	...	...	...	39.1	66	9	12	19	49.9	28.4	21.5	38	9	7	1	...	...	2.39	3	7	8	11	11	W	...	W	Prof. J. A. Swigart.
Lancaster,*	Lancaster,	413	30.21	30.72	29.06	41.8	64	10	12	30	50.9	33.7	18.2	30	10	10	5	81.6	34.4	1.60	...	5	11	13	6	NW	...	NW	Lewis T. Lampe.
Lawrence,	Newcastle,	903	...	...	...	41	73	9	13	30	48.4	30.2	18.2	35	8	6	22	...	...	3.02	4	7	4	17	19	SE	SE	SE	Wm. T. Buts.
Lebanon,	Lebanon,	474	30.18	30.80	29.20	39.5	62	23	13	30	50.1	31.1	19	46	22	8	5	76.7	31.1	2.44	0.3	10	7	13	10	NE	SW	NE	Geo. F. Hare, C. E.
Lehigh,	Coopersburg,	550	...	...	...	39.7	64	12	13	30	50.5	31.1	19.4	32	17	6	29	...	...	2.27	...	10	11	8	11	NW	NW	NE	Dr. M. H. Boye.
Luzerne,*	Drifton (25 days),	1,655	30.17	30.55	29.38	34.9	57	23	8	30	44.9	24.9	20	31	9,18	10	24, 27	72.6	30.9	4.98	0.2	5	8	12	8	...	...	...	J. R. Wagner.
Luzerne,	Wilkesbarre,	575	...	...	...	40.4	66	9	18	18, 30	50.8	29.6	21.2	39	8	11	29	...	...	2.63	2	9	12	1	17	NW	...	NW	A. W. Betterly.
McKean,	Smethport,	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
Montgomery,	Pottstown,	150	...	...	...	42.5	66	10	14	30	53.8	32.6	20.5	33	17	5	23	76.9	34.5	1.85	...	5	17	5	8	W, NW	W	W	Charles Moore, D. D. S.
Philadelphia,	Philadelphia Weather Bureau,	117	30.20	30.84	29.38	44.2	66	10	15	30	51.6	36.9	14.7	27	17	3	29	72	33.5	1.70	...	9	11	9	10	NW	...	NW	Luther M. Dey, Observer.
Philadelphia,	Philadelphia (Centennial avenue),	130	30.20	30.84	29.37	44.7	67	10, 12	15	30	53.3	35.7	17.6	33	17	9	11	79	35.8	2.06	...	9	13	10	17	NW	NW	NW	John Comly.
Schuylkill,	Girardville,	1,080	30.13	30.67	29.37	37.2	63	11	12	30	48.5	29.3	17.3	30	17	6	29	...	...	2.31	0.5	9	16	6	8	W	W	W	E. C. Wagner.
Snyder,	Selinsgrove,	445	30.19	30.73	29.43	39.6	56	23	20	20	48.7	37.2	18.5	37	17	5	1	81.8	34.1	3.55	1	8	7	10	13	NW	NW	NW	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	38.2	66	8	7	19	46.5	27.1	19.4	37	7	7	15	85.5	34.1	2.45	0.5	7	3	6	21	SW	SW	SW	W. M. Schrock.
Tioga,	Wellsboro,	1,337	30.12	30.74	29.17	34.4	64	9	10	29	43.2	26.1	17.1	30	8	6	1	81.9	68.2	4.21	5.5	12	2	9	19	N	S	S	H. D. Deming.
Union,	Lewisburg,	450	...	...	...	40.6	68	8	13	30	49.1	32.1	17	30	8	4	5,27	...	...	3.45	1	7	11	9	10	SW	SW	SW	F. O. Whitman.
Warren,	Columbus,	1,416	...	...	...	37.4	70	9	10	19	44.2	30.6	13.6	40	7	0	17	62.6	33.5	5.70	3	20	2	8	20	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	34.5	66	8	6	30	46.1	24.3	22.8	46	8	4	11	...	...	1.65	2	8	6	13	11	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	36.3	60	17	8	30	45.4	27.2	18.2	34	9,17	4	11	...	...	1.82	0.5	8	...	...	...	...	...	...	John Torrey.
Westmoreland,	Ligonier,	1,750	...	...	...	41	73	9	7	19	50.8	28.3	25.5	55	19	8	23	...	...	2.93	...	12	9	12	9	...	...	...	J. T. Ambrose.
Wyoming,*	South Eaton,	660	...	...	...	36.2	64	9	13	30	49	29.4	19.6	37	8	5	30	...	...	2.84	1	8	7	4	19	S	...	S	Benj. M. Hall.
York,*	York,	385	30.11	30.72	29.35	39.4	66	10	10	30	52	30.1	25.3	40	8	11	25	84.4	33.6	2.13	1	10	14	5	11	NW	...	NW	Mrs. L. H. Grenewald.

*Observations taken at 8 a. m. and 8 p. m.

†Observations taken at noon.

L. M. Dey, *Observer in Charge.*

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Summary of Meteorological Observations taken during the Year 1891, at the Pennsylvania State Weather Service Station, Emporium, Cameron County, 1,300 feet above tide, by T. B. Lloyd, Voluntary Observer.

Months. 1891.	Temperature. Highest.	Lowest.	Average.	Average range.	Precipitation. Rain and melted snow.	Rainy days.	Snow in inches.	Weather. Clear.	Fair.	Cloudy.	Wind. 1891.	1890.	1889.
January,	51°	3°	30°	16°	5.47	9	1	4	8	19	NW	W	W
February,	61°	4°	34°	18°	4.56	13	6½	4	9	15	W	W	W
March,	62°	*4°	36°	19°	5.12	11	16½	7	8	15	E	W	W
April,	83°	17°	48°	28°	2.33	8	. . .	13	10	8	W	W	W
May,	83°	25°	60°	30°	1.06	5	. . .	12	7	12	NW	W	W
June,	92°	39°	68°	29°	4.45	12	. . .	15	8	7	NW	W	W
July,	90°	39°	69°	25°	8.46	12	. . .	12	8	11	W	W	NW
August,	92°	43°	68°	23°	5.40	14	. . .	3	20	8	E	NW	NW
September,	88°	32°	66°	26°	1.17	9	. . .	18	7	5	W	NW	W
October,	85°	25°	48°	23°	5.48	8	. . .	11	7	13	W	NW	NW
November,	66°	9°	39°	18°	4.01	12	2½	7	3	20	W	W	W
December,	58°	8°	37°	20°	4.06	11	2½	11	8	12	W	NW	W
					48.37	124	29	116	103	145	. . .	. . .	. . .

* Below zero.

Summaries for 1889, 1890 and 1891.

Temperature.

Annual mean temp., 1889,	50.5°
Annual mean temp., 1890,	51.2
Annual mean temp., 1891,	50.2
Highest temp., July, 1889,	93
Highest temp., July, 1890,	94
Highest temp., June and August, 1891,	92
Lowest temp., February, 1889, below zero,	20
Lowest temp., March, 1890, below zero,	13
Lowest temp., March, 1891, below zero,	4
Extreme annual range temp., 1889,	113
Extreme annual range temp., 1890,	107
Extreme annual range temp., 1891,	96
Average monthly range temp., 1889,	23.8
Average monthly range temp., 1890,	23
Average monthly range temp., 1891,	23

Precipitation.

(In inches and hundredths.)

Rain and melted snow, 1889,	47.89
Rain and melted snow, 1890,	63.26
Rain and melted snow, 1891,	48.37
Average monthly precipitation, 1889,	3.99
Average monthly precipitation, 1890,	5.27
Average monthly precipitation, 1891,	4.03
Greatest monthly precipitation, 1889, May,	8.04
Greatest monthly precipitation, 1890, May,	9.61
Greatest monthly precipitation, 1891, July,	8.46
Least monthly precipitation, 1889, March,	1.44
Least monthly precipitation, 1890, November,	2.16
Least monthly precipitation, 1891, May,	1.06
Greatest daily rainfall, 1889, May 31,	5.85
Greatest daily rainfall, 1890, September 10,	2.41
Greatest daily rainfall, 1891, July 25,	2.25

Wind.

Prevailing wind, 1889,	West.
Prevailing wind, 1890,	West.
Prevailing wind, 1891,	West.

Weather.

Number days rainfall, 1889,	119
Number days rainfall, 1890,	143
Number days rainfall, 1891,	124
Clear days, 1889,	105
Clear days, 1890,	92
Clear days, 1891,	116
Fair days, 1889,	121
Fair days, 1890,	107
Fair days, 1891,	103
Cloudy days, 1889,	139
Cloudy days, 1890,	166
Cloudy days, 1891,	145

Late and Early Frosts.

May 29.	September 23, 1889.
May 18.	September 28, 1890.
May 27.	September 30, 1891.
Frost July 21, 1890.	

Snow Fall.

	Inches.
Winter of 1888 and 1889,	33
Winter of 1889 and 1890,	25
Winter of 1890 and 1891,	56½
Winter of 1891 and 1892 to January 16,	14½
1889, February,	13½
1889, March,	3½
	17
1890, February,	8
1890, March,	14½
	22½
1891, February,	6½
1891, March,	16½
	23

Summary of Meteorological Observations taken during the year 1891, at the Pennsylvania State Weather Service Station, Girardville, Schuylkill county, Pennsylvania, 1,000 feet above tide, by E. C. Wagner, Voluntary Observer U. S. Signal Service.

Months.	Average pressure of atmosphere by barometer.	Temperature.			Precipitation.		Weather.			Predictions Verified.	
		Highest.	Lowest.	Average.	In inches and hundredths.	Number of days rain or snow fall.	Clear.	Fair.	Cloudy.	Weather.	Temperature.
January,	30.093 in.	53°	10°	32°	8.74	13	8	14	9	80 p. c.	86 p. c.
February,	30.053 in.	57°	10°	34°	4.36	13	8	8	12	88 "	88 "
March,	30.065 in.	58°	7°	30°	4.08	14	14	6	11	90 "	90 "
April,	29.982 in.	79°	23°	51°	3.54	10	19	4	7	84 "	88 "
May,	30.010 in.	85°	31°	58°	1.80	11	18	8	5	85 "	91 "
June,	29.936 in.	92°	40°	66°	3.70	10	23	4	3	86 "	85 "
July,	29.907 in.	96°	48°	69°	9.64	13	19	2	10	81 "	80 "
August,	29.900 in.	89°	38°	64°	2.47	10	9	11	11	85 "	92 "
September,	30.120 in.	84°	41°	63°	1.90	6	19	9	2	92 "	88 "
October,	30.080 in.	80°	27°	54°	3.77	8	14	10	7	85 "	92 "
November,	30.127 in.	63°	12°	37°	5.12	9	16	6	8	80 "	85 "
December,	30.142 in.	60°	8°	34°	6.23	10	15	8	8	86 "	90 "
					62.44	127	182	90	93		

Highest reading of barometer, December 31st. . . . . 30.531 inches.
Lowest reading of barometer, January 22d. . . . . 29.429 inches.
Highest reading of thermometer, June 15th and 16th. . . . . 97°.
Lowest reading of thermometer, March 2d. . . . . 7°.
Range of thermometer during the year. . . . . 85°.
Total snow fall for the year. . . . . 42.75 inches.
Total precipitation for the year. . . . . 62.44 inches.
Average monthly precipitation. . . . . 5.203 inches.

Greatest monthly precipation, July. . . . . 9.64 inches.
Least monthly precipitation, May. . . . . 1.80 inches.
Greatest daily rainfall, August 23d. . . . . 3.90 inches.
Precipitation 1887. . . . . 48.73 inches.
Precipitation 1888. . . . . 62.62 inches.
Precipitation 1889. . . . . 70.27 inches.
Precipitation 1890. . . . . 64.08 inches.
Precipitation 1891. . . . . 62.44 inches.